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EVAPORATION AND SOIL MOISTURE IN RELATION TO THE SUCCESSION OF PLANT ASSOCIATIONS

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 191

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(WITH TWENTY-SEVEN FIGURES)

I. Evaporation

The water conditions of plants have long been recognized by ecologists to be matters of the highest importance, but unfortunately it has seldom been possible to describe these conditions in other than the most general qualitative terms. The only factor affording quantitative data has been precipitation, and this is only indirectly related to plant production on account of the many irregular variations that exist between the amount of rainfall and the quantity of water available for plant growth. In a general way, and especially in dealing with large areas, a fairly close relationship may be established, but within the different habitats of a single region no such connection can be recognized.

In a study of water conditions, two phases of the subject are of importance. They are the direct source and amount of the supply and the region and cause of the loss. The latter is a climatic, the former largely an edaphic, problem, for it is evident that plants derive their moisture from the soil and lose it into the air, and for the quantitative solution of these problems it is necessary to measure the power of the air to extract water from the plant; in other

words, the evaporating power of the air, and the amount of moisture in the soil available for the use of plants. Such measurements have been carried on in certain parts in the Chicago region in an effort to establish a relation between the moisture conditions and the succession of plant associations.

The researches of LIVINGSTON (1) and others have shown that the evaporating power of the air is a rather satisfactory summation of all the atmospheric factors that determine and limit the growth of plants, since it indicates the power of the atmosphere to extract water from their aerial parts, and has been shown in general to vary almost directly with their rate of transpiration. He has also devised the porous cup atmometer and shown that it is able to measure this power with a very considerable degree of accuracy during the growing season, or rather during that portion of the year free from frost, which in the Chicago region is practically the same as the growing season. Hence, during the three seasons of 1910–1912 stations with these atmometers were established and maintained in six distinct plant associations in the Chicago region. Since nowhere in this region is a succession of associations more clearly marked or more easily determined than upon the sand dunes immediately south of Lake Michigan, it seemed that a large number of the determinations should be made within this area. This vegetation has been described by COWLES (2), who has shown that the forest succession consists principally of associations dominated by cottonwood, pine, black oak, white and red oak, and beech and maple, in the order named. These represent a continuous series extending from pioneer trees to the mesophytic climax forest of the region. The physiographic factors, the detailed composition of the associations, the variety of the transitional forms, and the frequency of retrogression have been so well explained by COWLES that further detailed discussion at present seems unnecessary. While all the associations mentioned occur upon the sand dunes in the order indicated, it was found to be impossible to obtain easy access to the two final stages of the succession upon sand, and hence the oak-hickory and beech-maple forests were upon clay soil. Objections may be urged against such a selection, and many are recognized by the writer, but it is maintained that the comparisons

that have been made in this investigation are quite legitimate ones, and, further, it is hoped that future studies may supply the lacking data for these associations upon a sandy soil. In addition to this successional series of associations, through the cooperation of some of the writer's students, data were obtained from the edaphic prairie characteristic of the Chicago region.

The period of investigation was during 1910, from May 6 to October 31 (178 days); during 1911, from May 1 to October 28 (180 days); and during 1912, from May 3 to October 22 (172 days), the records for the oak-hickory forest and the edaphic prairie being for the seasons of 1911 and 1912 only. Weekly visits were made to all stations throughout this period, except to those of the beech-maple forest, which were visited once in two weeks. A preliminary report of much of the data obtained during the first season has already appeared.[1]

INSTRUMENTS AND METHODS

The instruments employed were mostly the porous cup atmometer devised by LIVINGSTON, although during the first season a few of the type described by TRANSEAU (3) were also used. The atmometers were mounted in wide-mouthed bottles, having a capacity of 500 cc., closed with tightly fitting cork stoppers that were perforated for the atmometer tubes and for bent capillary glass tubes which served to equalize the atmospheric pressure within the bottles with that of the exterior air, without causing any loss by evaporation or permitting rainwater to enter the reservoir. The bottles were sunk in the soil about two-thirds of their height, so that the evaporating surface of the instruments was 25–20 cm. above the surface of the soil. Except where otherwise specified, the readings were made weekly by filling the bottles from a graduated burette to a file scratch on the neck. The small area of the water surface at this point made the probable error in readings less than 0.5 cc., and this could have had no appreciable effect upon the results. The instruments were all standardized to the same unit before being used, restandardized at intervals of 6–8 weeks during the season, a revolving table being used for the purpose similar to

[1] BOT. GAZ. **52**:193–208. 1911.

that described by NICHOLS (4), and a final correction made on their being collected in the autumn. By the coefficients thus obtained, all readings were reduced to the standard adopted by LIVINGSTON (5), the directions he gives being so closely followed that it is unnecessary to detail further the methods used in operating the instruments. Three or more stations were always maintained in each association, the mean of the various readings being taken as giving the true measure of the evaporating power of the air for that association.

In most instances no correction has been made for errors caused by rainfall, although during showers some water undoubtedly passes into the porous cup and into the reservoir, because it was thought that the amount of variation thus produced would be the same for all stations within so limited an area, and hence the comparative relation of results would remain unchanged. This assumption has been largely verified by BROWN (6), using an atmometer with a rain-correcting valve, and also by the experience of the writer by maintaining control instruments with the valves. The record for the prairie association for 1911 was wholly, and that for the oak-hickory forest for 1912 was partially, made with rain-correcting atmometers.

In order to facilitate comparisons between the various stations, and to exhibit the progress of the evaporation rate during the entire season, the average water-loss per day between the weekly readings has been calculated, and the results expressed in graphs, with ordinates representing the number of cubic centimeters lost per day by a standard atmometer, the abscissas being the intervals between the weekly readings. The readings included within each calendar month are indicated at the top of the diagram. For convenience of reference, the stations are numbered consecutively, beginning with those of the association of lowest rank, that is with those of the cottonwood dune.

PLANT ASSOCIATIONS AND STATIONS

The stations established in the plant associations upon the sand dunes were all upon an area of dunes lying between the little village of Miller, Indiana, and the southern shore of Lake Michigan. The shore at this point is gradually encroaching upon the lake

because of the material being deposited off shore. This being swept inward by the waves and wind forms increasing areas of dunes, at first quite bare, but with forests soon advancing upon them. Grasses and shrubs constitute the first vegetation, but in the moist depressions the seeds of the cottonwood (*Populus deltoides*) germinate, and some of the seedlings are able to maintain themselves. A more detailed account of their establishment has been given elsewhere by the writer (7), and it is sufficient here to note that they surmount the moving dunes and at a distance of 100–200 meters from the shore establish the pioneer tree association that may be designated the cottonwood dune association, or more briefly the "cottonwood dune." This persists upon more or less actively moving sand, forming dunes varying in size up to 20 or even 30 meters or more in height, until from various causes, among which the vegetation is the most important, movement is checked and the dunes become fixed. It is an association of a single tree species and a paucity of shrubs and herbs, all having strongly xerophytic structures. Among the prominent species are *Salix glaucophylla*, *S. syrticola*, *Prunus pumila*, *Cornus stolonifera*, *Calamovilfa longifolia*, *Ammophila arenaria*, and a very few annual and perennial herbaceous plants.

In this association, upon dunes that had become almost completely fixed (fig. 1), four stations were established, each with at least one atmometer. These stations were about 200 meters from the lake shore, some 100 meters apart, and about 12 meters above the level of the waters of Lake Michigan. Three of these stations were upon comparatively level areas, surrounded by the usual open stand of cottonwoods and willows (fig. 2). At all stations the atmometers received a small amount of shade for a few hours of the day, and on account of the open nature of the association were little sheltered from the wind, the cups receiving a rather sharp sand blast during high winds. The differences of exposure to winds probably caused some of the variations in the records of the different stations, but affected very slightly the average rate for the season. Station 4 was upon the leeward slope of a very slowly advancing dune, and was further sheltered by a good stand of *Cornus stolonifera*. It was about 3 meters below the crest of

the dune upon an eastern exposure. This station was maintained only during the season of 1910. A detailed report of the atmometer readings for the four stations during the season of 1910 is shown in fig. 3, where in addition to the evaporation records the weekly rainfall in centimeters at Chicago during the summer months is plotted. As it has been possible to establish no direct relationship between rate evaporation and the occurrence and amount of precipitation, rainfall data are omitted from the remaining diagrams.

FIG. 1.—Sand dunes with *Populus deltoides* or the cottonwood dune association still moving slowly over an area with *Pinus Banksiana*, *P. Strobus*, etc.; Miller, Ind.

An examination of these graphs will at once show that the rate of evaporation was high and subject to sudden and considerable changes. There was no great divergence in the rate at stations 1, 2, and 3, but the rate at station 4 was decidedly lower, showing the modifying influence of the shrub cover in creating less extreme conditions, which permit the entrance and establishment of species of less xerophytic nature, which eventually form the succeeding association. Thus not only does the nature of the vegetation control to a great extent the evaporation beneath it, as pointed out

by GLEASON (8) and others, but the evaporation thus controlled and changed is one of the principal factors in causing the development of a different vegetation, or, in other words, the decreased rate of evaporation caused by the heavier vegetation is the direct cause of succession between different associations. It seems surprising that GLEASON has reached an opposite conclusion from somewhat similar data.

An average of the records of stations 1, 2, and 3 is plotted for comparison with similar records from the other associations (fig. 4).

FIG. 2.—Dune with *Populus deltoides* and *Salix syrticola;* station 3; Miller, Ind.

Here it will be seen that the maximum average evaporation for any week of 1910 was just above 32 cc. per day, and the minimum only once fell below 12 cc. per day. The average for the entire season of 178 days was 21.1 cc. per day. In 1911 several days in May, with a temperature above 90° F., caused a remarkable maximum of 47 cc. per day in that month (fig. 5), and serves to emphasize the importance of records extending through several seasons. The midsummer maximum was 42 cc. per day, the minimum 11.5 cc., and the average 24.6 cc. per day. The season of 1912, on the

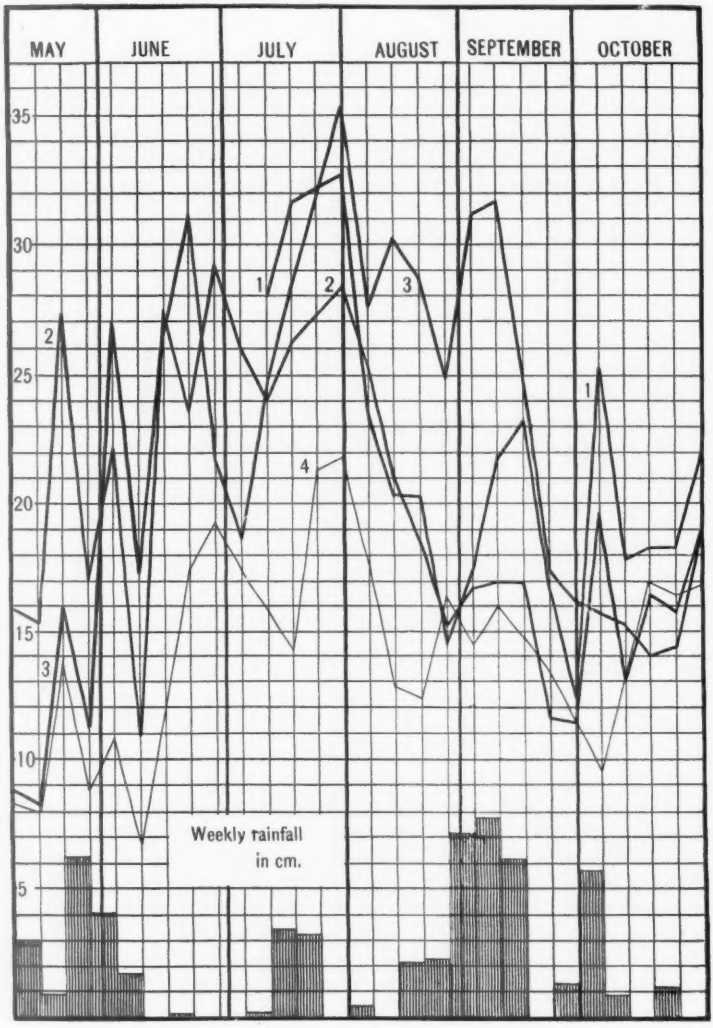

FIG. 3.—Daily evaporation rates in the cottonwood dune association at stations 1, 2, 3, and 4, during the season 1910.

contrary, was one of less extremes (fig. 6), giving a maximum evaporation rate of only 31 cc. per day and a minimum of 12.2 cc., while

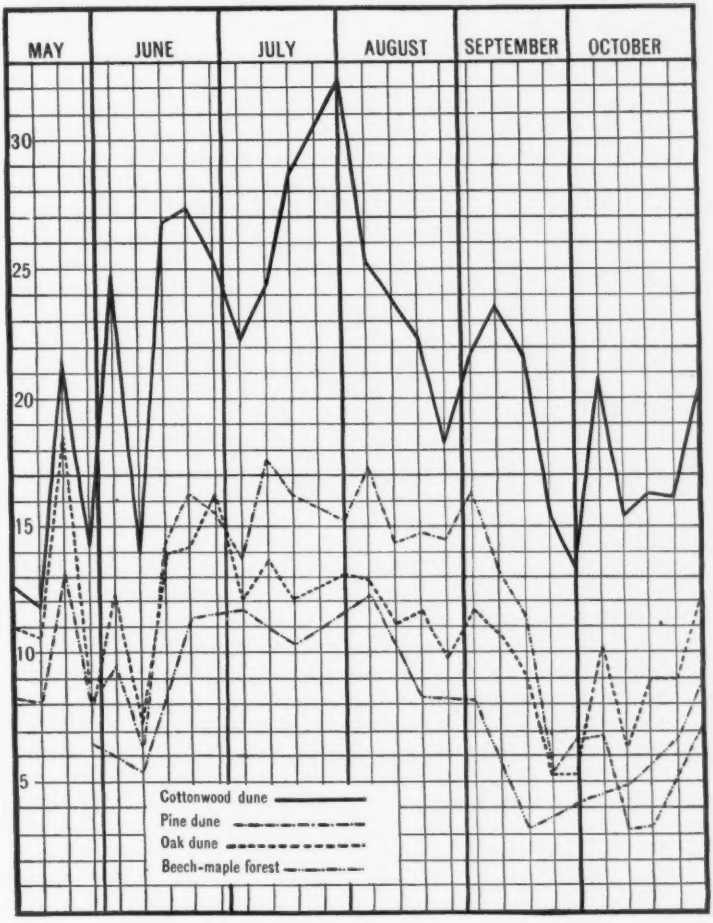

FIG. 4.—Mean daily evaporation rates in the different associations during the season 1910.

the average was almost identical with that of the first year, amounting to 21.3 cc. per day. Here the general results of the three

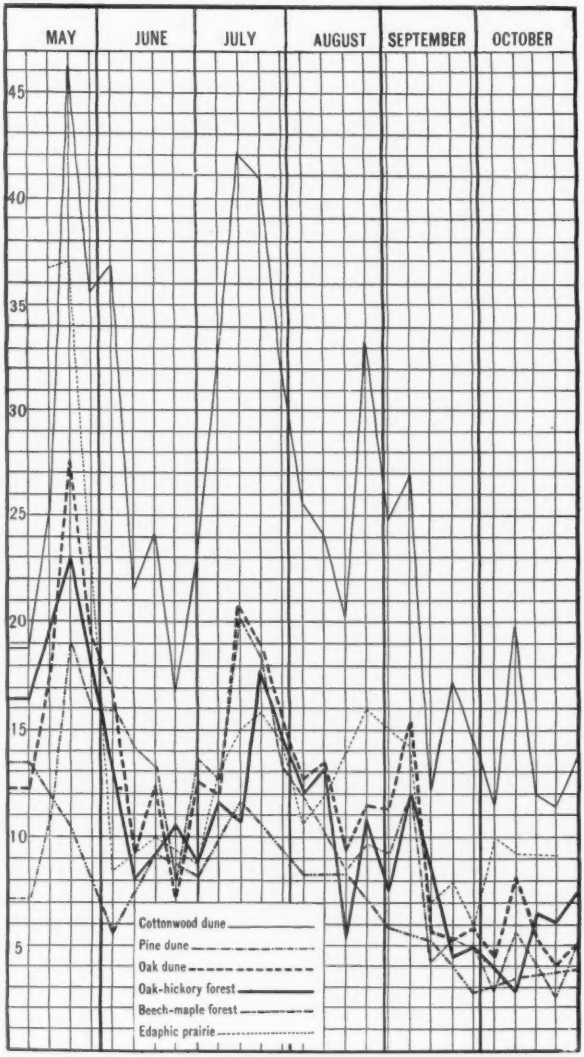

FIG. 5.—Mean daily evaporation rates in the different associations during the season 1911.

seasons investigated are seen to be consistent, and to indicate that not only is the cottonwood dune an association with a very high

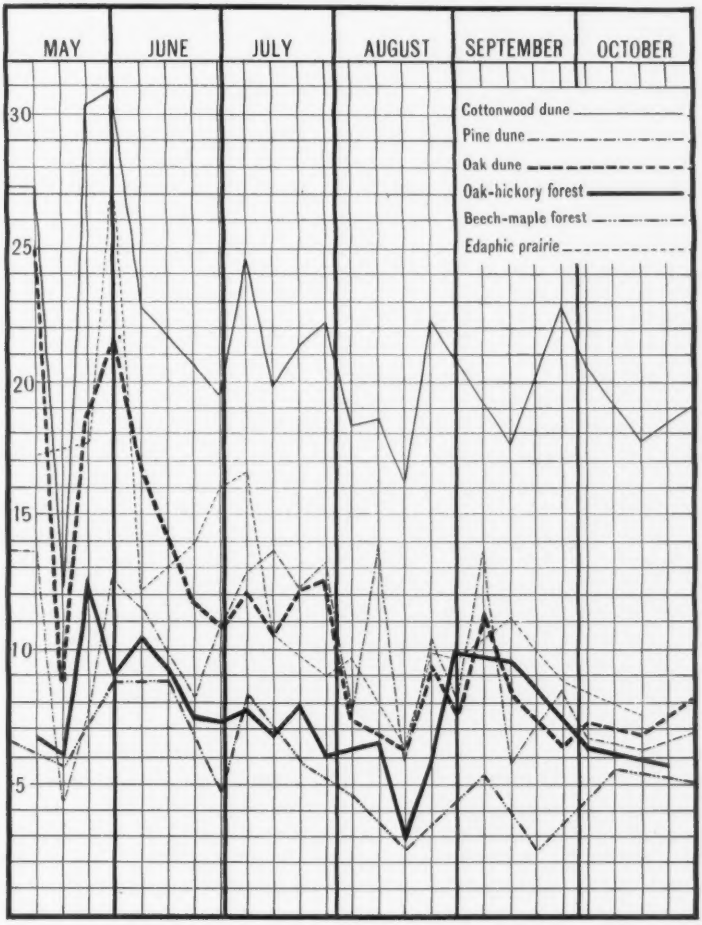

FIG. 6.—Mean daily evaporation rates in the different associations during the season 1912.

rate of evaporation, but also that it is subject to excessive variation. This is very noticeable during May and June, and prevails to a less

extent during the remainder of the season, the fluctuations being markedly greater than in the other associations.

With the fixation of dunes and the increase of grasses and other herbaceous vegetation, seedlings of conifers develop and give rise to an evergreen forest association succeeding the cottonwood, and here designated the pine dune association (fig. 7). This association varies somewhat in composition in different localities, but in the area under consideration is dominated by *Pinus Banksiana*,

FIG. 7.—Dune with *Pinus Banksiana*, *P. Strobus*, *Juniperus communis*, etc.; station 6; Miller, Ind.

associated with *Juniperus virginiana*, *J. communis*, and in older portions with *Pinus Strobus*. In the undergrowth *Arctostaphylos Uva-ursi* is conspicuous, associated with *Rhus canadensis*, *R. toxicodendron*, *Prunus virginiana*, *Celastrus scandens*, seedlings of *Quercus velutina*, *Smilacina stellata*, *Asclepias tuberosa*, *Monarda punctata*, and other woody and herbaceous plants. It is evident that this association is unique in the dominance of evergreens, while its limited extent shows that it is comparatively short-lived, a

fact that is emphasized by the presence, very early in its history, of seedlings of *Quercus velutina*, the dominant tree of the succeeding association.

In this association, stations 5, 6, and 7 were placed at spots of medium density of growth, about 100 meters south and east of the cottonwood dune series. The averages of the readings from the three stations are plotted for comparison with similar data from the other associations (figs. 4, 5, 6). Compared with that of the preceding association, the rate of evaporation is seen to be much lower and subject to less violent fluctuations. The maxima and minima are nearly synchronous with the preceding and succeeding associations, the most remarkable feature being the very low comparative rate during the weeks of May and October, when the deciduous associations are largely without foliage. The maximum for 1910 (fig. 4) was 17.5 cc. per day, the minimum fell below 4 cc., and the average rate for the season was 11.3 cc. daily.

The next season the maximum rate was 20.2 cc. per day (fig. 5), the minimum 2.5 cc. per day, and the average 10.3 cc.; while in 1912 (fig. 6) the maximum was only 13.7 cc. per day, the minimum rose to 4 cc. per day, but the average was reduced to 9.7 cc. per day, again demonstrating the fact that 1912 was a season of moderate climatic conditions.

Proceeding inland from the lake shore, the pines gradually decrease in number, and the black oak (*Quercus velutina*) becomes more plentiful, until at a distance of about 500 meters south of the last group of stations it forms an almost pure stand, with only occasional trees of white oak (*Quercus alba*). The shrubby under-growth consists principally of *Prunus virginiana*, *Rosa blanda*, *Viburnum acerifolium*, *Vaccinium pennsylvanicum*, *Ceanothus americanus*, and seedlings of *Quercus velutina* and *Q. alba*. Among the herbaceous members of the association are *Smilacina stellata*, *Lupinus perennis*, *Tephrosia virginiana*, *Lithospermum canescens*, *Asclepias tuberosa*, *Helianthemum canadense*, *Polygonella articulata*, and *Aster linariifolius*. In this oak dune association four stations were placed: nos. 8, 9, and 10 in the stands of average density (fig. 8), and no. 11 in one of the very characteristic openings sparsely covered by xerophytic grasses, together with such plants

as *Monarda punctata*, *Asclepias tuberosa*, and *Opuntia Rafinesquii*. This last station was maintained only during the seasons of 1910–1911, and, owing to a series of accidents, its record was by no means continuous, especially during the latter season. During 1910 (fig. 9) its rate of evaporation was decidedly in excess of that of the other stations, especially in June and July. The records of the other stations are quite comparable and their average appears in fig. 4.

FIG. 8.—Dune covered with open forest of *Quercus velutina;* station 10; Miller, Ind.

In 1910 (fig. 4) a maximum of nearly 19 cc. per day occurred in May, before the trees were in full foliage, and similar high rates at the same season of the year were seen in 1911 (fig. 5), when it rose to the surprising height of 27.5 cc. per day; while in 1912 (fig. 6) it was 21.5 cc. per day. This could hardly be a critical period for vegetation, on account of the abundant supply of water in the soil (see second part of this paper), although it might be decisive for many young seedlings, and it may therefore be disregarded in the general discussion.

Midsummer afforded maxima of 16 cc. in 1910, 18.9 cc. in 1911, and 12.5 cc. in 1912, the minima for these years being respectively

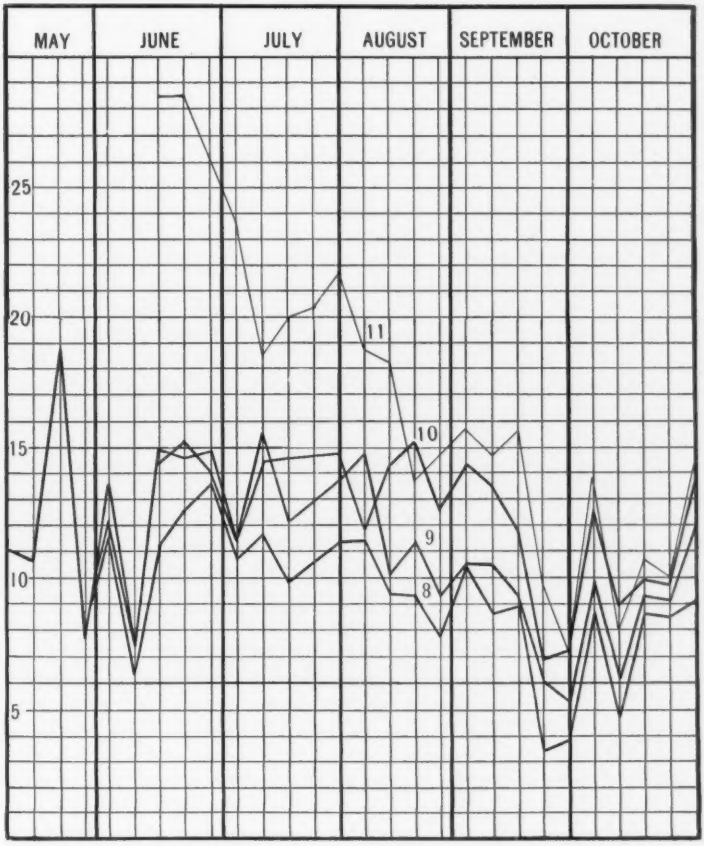

FIG. 9.—Daily evaporation rates in the oak dune association; stations 8, 9, 10, and 11 during the season 1910.

5 cc., 4 cc., and 6.3 cc. per day, while the averages for the seasons were 10.3 cc., 11.8 cc., 10.9 cc. daily (figs. 4, 5, 6).

The forest association dominated by *Quercus velutina* is rather persistent upon the dunes, but is gradually changed by the invasion

of other more mesophytic trees, notably the red and white oaks (*Q. rubra* and *Q. alba*) and one or two species of *Carya*, eventually giving rise to a fairly mesophytic association, commonly designated the oak-hickory forest. Although rather abundant in the Chicago region, it does not seem desirable to enter here upon any discussion of its occurrence or composition, especially as it has been excellently described by COWLES (**9**). Similar reasons are sufficient for very brief descriptions of the other associations included within the scope of this paper.

The most accessible, comparatively undisturbed area of this association near the city of Chicago is found about 15 miles southwest of Miller, Indiana, at Palos Park, Illinois, where it has developed upon morainic clay. Here stations 12, 13, and 14 were established in 1911 by one of my students, Mr. WADE MCNUTT, in the typical upland mesophytic forest, and station 15 in a depression which was really the floor of a broad shallow ravine and comparable in most respects to a floodplain. In the depression there were, in addition to the trees of the upland, such typically floodplain species as the white ash (*Fraxinus americana*), the elm (*Ulmus americana*), and the black walnut (*Juglans nigra*). A more detailed description of the forest and an analysis of the results of 1911 have already appeared (**10**). In this year there was an average midsummer maximum rate of 17.5 cc. per day (fig. 5) from stations 12, 13, and 14; a minimum rate of 2.7 cc.; and an average for the season of 180 days of 9.8 cc. per day. In 1912 the midsummer maximum was 10 cc. daily (fig. 6), the minimum the same as the preceding year, while the average was reduced to 7.8 cc. daily. Comparing this rate with that exhibited by the mesophytic floodplain forest of the depression, we find that the latter had a maximum of 16.2 cc. daily in 1911, a minimum of 1.7 cc., and an average of 8.3 cc. daily (**10**). In 1912 the maximum was reduced to 8 cc. daily, the minimum to 1.5 cc., and the average rate was only 4.2 cc. daily (fig. 10).

The climax of mesophytic conditions in the northern United States appears to be a forest in which the beech (*Fagus grandifolia*) and the maple (*Acer saccharum*) are conspicuous members. The succession upon the sand dunes is found to attain this climax, a

good instance being seen at Sawyer, Michigan, but unfortunately for the purposes of our investigation no such area was available nearer Chicago, and hence recourse was had to a good tract of beech-maple forest at Otis, Indiana, about 20 miles east of the stations at Miller. In this forest, in addition to the two dominant trees, there were a few individuals of *Tilia americana*, *Prunus serotina*, and *Liriodendron Tulipifera*, while notable in the undergrowth were seedlings of the principal trees, together with *Asimina*

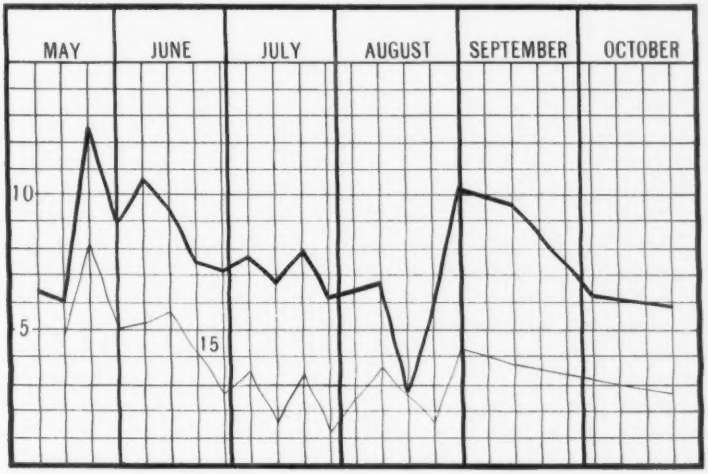

FIG. 10.—Daily evaporation rates in the oak-hickory forest for the season 1912; heavy line representing the mean rate for stations 12, 13, and 14, and light line that for station 15.

triloba, *Sambucus racemosa*, *Evonymus americanus*, and such herbaceous species as *Dicentra canadensis*, *Trillium grandiflorum*, *Adiantum pedatum*, *Polystichum acrostichoides*, *Viola rostrata*, and *Erigenia bulbosa*.

In this beech-maple forest, stations 16 (fig. 11), 17, and 18 were placed about 100 meters apart, upon the floor of the forest, station 19 in a rather narrow ravine (fig. 12) about 4 meters below the level of the others, while at station 20 the atmometer was attached to the branch of a tree 2 meters above the surface of the soil. The

last station yielded a very broken record during 1910; its record during 1911 has already been published (11), and at the end of that year it was discontinued, as other studies upon the evaporation rates in different strata were planned and in progress.

A comparison of the records of the five stations during 1911 will be found interesting and instructive (fig. 13). Stations 16, 17, and 18, upon the floor of the forest, show graphs of considerable regularity, differing but little from each other. Their combined average for the season was 7.4 cc. daily, and if this be compared with the

FIG. 11.—Beech-maple forest; station 16; Otis, Ind.

average rate from station 20, of 13.5 cc. daily, and from station 19, of 5.9 cc. daily, the proportional evaporating power of the air in the three strata will be found to be very nearly 1.84:100:0.80.

The average rates from the three stations upon the floor of the forest for the three seasons (figs. 4, 5, 6) gave maxima of 12.2 cc., 11.6 cc., and 8.1 cc. daily; minima of 3 cc., 2.8 cc., and 3.5 cc. daily; and seasonal averages of 8.1 cc., 7.4 cc., and 5.6 cc. per day respectively for the years 1910–1912.

It is interesting here to note the close correspondence between the records for this beech-maple forest and those obtained by

TRANSEAU (**12**) in a mesophytic forest containing a small percentage of beech, and situated on Long Island, New York, where for the period of observation from June 5 to July 2, 1907, the evaporation rate averaged 8.5 cm. daily, compared with 8.4 cm. daily during the month of June 1910, in the Otis, Indiana, forest, and 8 cc daily as the mean average rate for the midsummer weeks of the years 1910–1912 (table II). While it is not safe to draw any very definite conclusions from records covering but a single month, it

FIG. 12.—Ravine in beech-maple forest; station 19 about two-thirds down the right hand slope; Otis, Ind.

may be assumed that the two associations differ very little in the amount of mesophytism developed. It is to be regretted that similar comparisons cannot be made between the writer's results and those of GLEASON (**8**), but unfortunately the latter were not made with standard atmometers.

The edaphic prairie is a characteristic plant association of the Chicago region, and while it does not lie in the successional series with which this investigation is most particularly concerned, it was thought that it would be profitable to compare it with the various

forest associations. It seemed all the more urgent that it should be investigated because, with the growth of the city and the advance of agriculture, it is rapidly disappearing. Consequently, in 1911 the attention of Mr. E. M. HARVEY was directed to this portion of the problem and the range of evaporation and of soil moisture as determined, and the results have been published (**13**), but

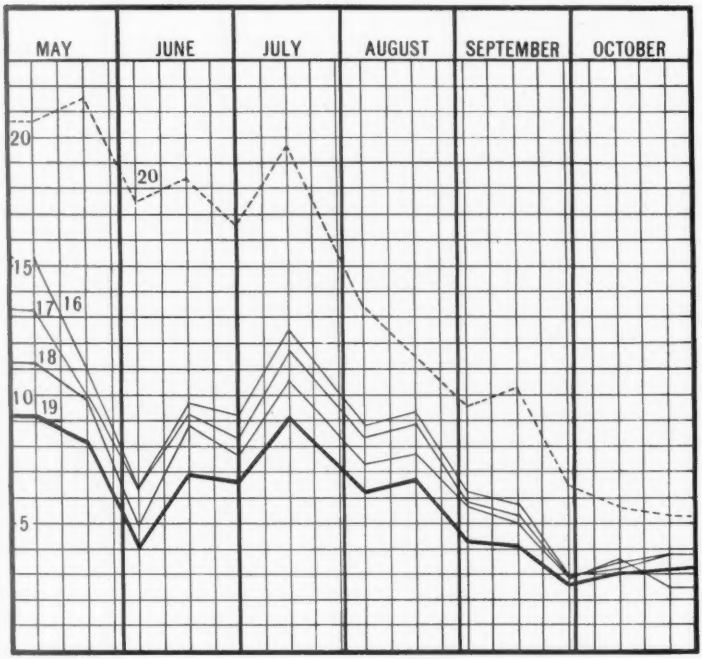

FIG. 13.—Daily evaporation rates in the beech-maple forest at stations 16, 17, 18, 19, and 20 during the season 1911.

through the courtesy of HARVEY, the averages for the year are included in fig. 5. The floristic composition of the prairie vegetation has been discussed by COWLES (**9**) and by HARVEY, and needs no further reference at present. This association seems to be the most usual stage in succession following the sedges in the filling up of shallow ponds and lakes formerly abundant in the Chicago region.

For the season of 1912 the prairie stations were under the efficient charge of Miss L. NEWLON, to whom the writer is indebted for the results here presented. During both seasons the range of the evaporation rate was great (figs. 5, 6), the vernal maxima being 37 cc. and 27 cc. daily, the midsummer maxima 16 cc. and 16.5 cc. daily; the minima 5.9 cc. and 6.1 cc.; while the average for each of the two seasons was 12.5 cc. per day.

GENERAL CONCLUSIONS

Several methods may be employed for comparing the data from the various associations. Perhaps the best is by means of the charts upon which the daily average rate by weeks for all the associations are plotted together (figs. 4, 5, 6). Here the characteristics of the different rates are represented graphically, and may be seen at a glance. Throughout the entire series the maxima and minima are generally coincident in time and proportionate in amount. Minor irregularities appear that it would be useless to attempt to explain. The different years show characteristically different curves. Thus, 1910 comes nearest to the commonly accepted ideas, with a somewhat regular curve increasing rather regularly from the beginning of the growing season, reaching a marked maximum about midsummer, and falling rather sharply with the humid weather of late August and September. The following year there are excessively high rates of evaporation in May (fig. 5), which will be found to correspond to a period of unusual weather conditions. The month had the highest temperature record for May experienced since the establishment of the Chicago Weather Bureau in 1871. The average temperature was 10° above normal, and for six days it reached or exceeded 90° F. The percentage of sunshine (79 per cent) was also greater than observed during any previous May. Moderate temperature conditions at midsummer, and a relative humidity slightly above the average, together with the percentage of sunshine below the normal mean are reflected in the general course of the evaporation graphs. The year 1912 is marked by a very moderate summer, the wind record of the weather bureau showing comparatively light air movement, while throughout July, August, and September the temperature

and sunshine records were considerably below the average. These weather conditions have resulted in very moderate and equable evaporation rates throughout all the associations and particularly in the more mesophytic (fig. 6). A further study of these diagrams in comparison with the data of the Chicago Weather Bureau would prove even more conclusively the assertion that the evaporating of the air represents a rather accurate summation of all the atmospheric factors that may be related to the water content of the aerial parts of plants. The differences in the records for the various years also prove the necessity of continued observation and extended records before definite conclusions are reached.

The records of 1911 and 1912 serve to give greater emphasis to some of the facts recorded and to the tentative conclusions arrived at during 1910 and published in the preliminary report[2] of these investigations. Thus, the evaporation rate of the cottonwood dune is farthest removed from the other associations, and by it there is exhibited not only a very great evaporating power, but also excessive and rapid variation, an increase or decrease of 50–100 per cent between the rates for consecutive weeks being not uncommon. This cannot but denote extremely rigorous conditions for the development of seedlings of ordinary herbaceous plants. The high midsummer maximum, apart from the question of soil moisture, would likewise prove an efficient factor in excluding all mesophytic plants.

Such graphs seem to depict rather well a habitat of atmospheric extremes, making large demands upon all available water, and naturally and necessarily resulting in a xerophytic plant association with a very limited undergrowth and an almost entire absence of herbaceous plants and seedlings. Perhaps nowhere could an association be found more entirely dependent upon vegetative reproduction for its maintenance, since almost without exception any increase in vegetation is the result of subterranean branches.

The records for this association, when considered in relation to the character of its vegetation and compared with those of the other associations, is believed to emphasize the fact that, although these data are for the lower stratum of the vegetation only, they are

[2] BOT. GAZ. 52:193–208. 1911.

for the critical one, especially in forest associations. Within this stratum develop all the seedlings, and upon their death or survival depends the character of the succeeding vegetation. Therefore, if the vegetation of an association so affects the evaporation rate of this stratum that it permits the survival of seedlings of more mesophytic species, it is evident that a more mesophytic association will develop and succession will be accomplished.

Any individuality in the graphs from the pine dune is plainly due to the evergreen character of the association, and is seen in the low rates in May and October, which are always decidedly below those of the succeeding oak dune association, and are often even lower than those of the oak-hickory and beech-maple forests. That this association is very close to the succeeding one may be seen by referring to table I. Here it will be seen that the mean

TABLE I

MEAN WEEKLY EVAPORATION RATES IN CC. FROM A STANDARD ATMOMETER FOR THREE SEASONS UNDER INVESTIGATION

Association	1910	1911	1912	Average	Comparative rates
Cottonwood dune	21.1	24.6	21.3	22.3	319
Pine dune	11.3	10.3	9.7	10.4	149
Oak dune	10.3	11.8	10.9	11.0	157
Oak-hickory forest	.....	9.8	7.8	8.8	126
Beech-maple forest	8.1	7.4	5.6	7.0	100
Edaphic prairie	.....	12.5	12.5	12.5	179

evaporation rates were during two of the three years slightly less than those of the succeeding association. The same is true for the average of the rates, but if the comparison be made for the 10 weeks of summer, from the last week of June to the first of September, as shown in table II, the comparative rates are reversed, and the pine dune association has a slightly higher average. This is believed to represent the actual condition during the weeks of greatest stress of moisture conditions.

The graphs of the oak-hickory and beech-maple forests seem to be without any special features other than that they depict the moderate conditions of truly mesophytic associations, while those of the edaphic prairie express the condition of an association

abounding in extremes and fluctuations inferior only to those of the pioneer association dominated by the cottonwood. As might be expected, there is a similarity between the evaporation rate of the prairie and that of the open areas of the oak dune (fig 9).

TABLE II

MEAN WEEKLY EVAPORATION RATES IN CC. FROM A STANDARD ATMOMETER DURING THE 10 MIDSUMMER WEEKS OF THE THREE YEARS UNDER INVESTIGATION

Association	1910	1911	1912	Average	Comparative rates
Cottonwood dune	25.0	30.2	20.3	25.2	315
Pine dune	14.1	12.6	10.3	12.3	154
Oak dune	12.1	13.4	10.1	11.9	149
Oak-hickory forest	.....	11.6	6.7	9.2	115
Beech-maple forest	10.2	8.5	5.3	8.0	100
Edaphic prairie	.....	15.1	12.4	13.7	171

It is interesting to note that comparative evaporation rates for all the associations, with the exception noted in the case of the pine dune, remain substantially the same whether the comparison is based upon the averages for the entire seasons (table I) or for the weeks of misdummer (table II) only. The comparison is perhaps more striking when the data are represented graphically, either for the individual seasons (fig. 14) or when the data for the three years are combined (fig. 15), when, if it be true that water conditions are the most important factors affecting the establishment of different plant associations, there can be no reasonable doubt that the progressive increase of the moisture content of the habitats indicated by the progressive decrease in the evaporation rates causes a corresponding progressive increase in the mesophytism of the plant associations as a whole, a change which we are accustomed to term *succession*.

As recommended in the writer's preliminary report (*loc. cit.*), the beech-maple forest is taken as the unit of comparison, and the evaporation rates in the other associations are expressed in terms of this unit. Thus, the beech-maple forest being represented by 100, the comparative evaporation rates for the midsummer weeks (table II) in the associations which precede it in the succession are respectively 115, 149, 154, and 315, showing a striking and progressive

increase in the humidity of this stratum of the vegetation as the succession advanced from the pioneer cottonwood to the climax beech-maple association.

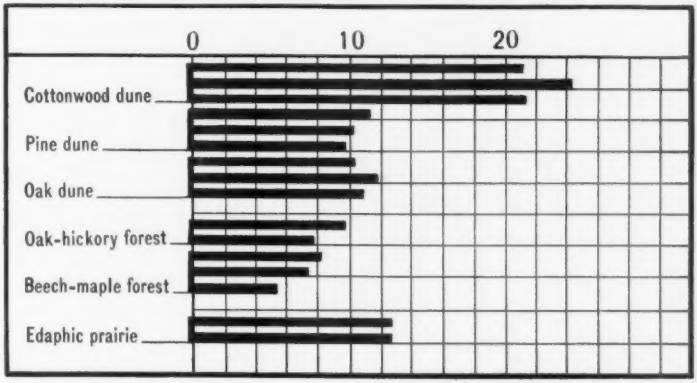

FIG. 14.—Diagram showing the comparative average daily evaporation rates in different associations for the seasons of 1910, 1911, and 1912.

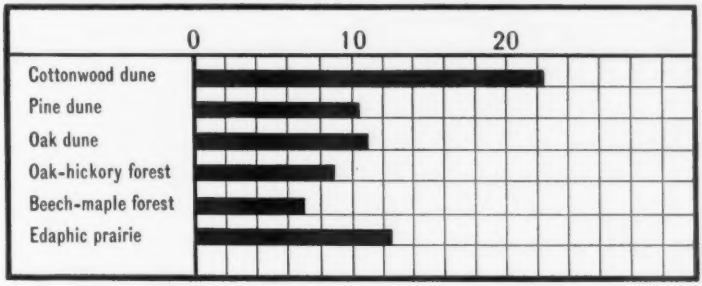

FIG. 15.—Diagram showing the comparative mean average daily evaporation rates in the different associations for the three seasons investigated.

II. Soil moisture

The direct source of the water supply of plants being the moisture in the soil, the amount of this moisture is evidently of the highest importance to vegetation. This has been recognized by many leading ecologists and phytogeographers, but very few data have been made available as to the effects of definite quantitative

amounts upon vegetation, or of the amount and range of the soil moisture in different plant associations. This has been largely due to the difficulty in relating the amount of moisture actually present in the soil to the production of vegetation. It is clear that there can be no direct relation between the percentage of water present in soils and the amount available for plant growth, for a sandy soil with 15 per cent of moisture is at or near saturation, while a stiff clay with 15 per cent of water is so dry that all plants wilt in it, even with a humid atmosphere.

Efforts have been made to establish a standard by which the actual water content of soils could be related to plant production. CLEMENTS (**14**) determined the amount of water remaining in soils when pronounced wilting occurred, and regarding this as non-available termed it the *echard*, while the difference between the amount actually present in the soil and the echard was the available water, or *chresard*. LIVINGSTON (**15**) recognized that the water-holding capacity of soils varied and had a fairly constant relation to the soil moisture conditions. Then BRIGGS and MCLANE (**16**) determined the *moisture equivalent* of soils by the application of a centrifugal force of 1000 times that of gravity, providing a method of measuring and comparing the retentiveness of different soils for moisture acted upon by a definite force. This had the advantage of being measured in absolute terms and of being reproducible within narrow limits of error. It remained for BRIGGS and SHANTZ (**17**) to refine the methods of determining the percentage of water in soils when permanent wilting occurs in such a plant as the standard Kubanka wheat, giving the *wilting coefficient*, and further to show that a constant relation exists between the moisture equivalent and the wilting coefficient; that is, $\frac{\text{moisture equivalent}}{1.84} = \text{wilting coefficient}$.

They also clearly demonstrated the fact that plants continue to take water from the soil long after the wilting coefficient is reached. The writer, believing that none of the water absorbed from soil whose moisture content is below the wilting coefficient is used for the growth of the organism, has used *growth-water* (**18**) for the soil moisture in excess of the wilting coefficient.

That the water content of the soil at the time of wilting, or, in other words, the magnitude of the wilting coefficient, is affected by excessive evaporation rates, causing very high transpiration rates, has been shown by BROWN (**19**) and by CALDWELL (**20**), although their work also goes to show that it holds perfectly within certain limits differing but slightly from those obtaining in ordinary mesophytic or semi-mesophytic habitats. Although the validity of these objections to the wilting coefficient in extreme conditions is recognized, it is nevertheless believed that it is, especially when determined by the indirect method of BRIGGS and SHANTZ, an efficient means of relating the range of soil moisture to the production of vegetation and an important addition to the equipment of ecological and agricultural investigators.

METHODS

The soil moisture determinations here reported were made in the plant associations described in the previous part of this paper during the years 1911–1912, and for the same months as the atmometer records. In making the determinations, weekly samples, each consisting of 200 to 250 grams of soil, were taken in each of the associations at depths of 7.5 cm. and 25 cm. In order to provide against unnecessary error, each sample consisted of two portions of some 100 grams each, taken from spots several meters apart, care also being taken that no soil was taken nearer than a meter to holes where previous samples had been dug. The soil was placed in wide-mouthed jars, tightly sealed, brought to the laboratory, weighed and dried at a temperature of 100° to 104° C. until it reached a constant weight (about 5–7 days). The percentage of water to the dry weight of the soil was then calculated.

The wilting coefficients of the same soils were determined by both the direct and the indirect methods of BRIGGS and SHANTZ (**17**). The results from the two methods agreed within the limits of experimental error, which appeared to be much greater in the direct method. This was particularly noticeable in the sandy soil of the dunes, where the wilting coefficient approximates 1 per cent. All the wilting coefficients are the averages of at least 10 determinations.

Those of the clay soils made by the centrifuge, using the formula

$$\frac{\text{moisture equivalent}}{1.84} = \text{wilting coefficient},$$

the moisture equivalent being the amount of water which the soil retains against a centrifugal force of 1000 times gravity, showed very constant results.

The results are represented graphically, the wilting coefficients being represented by broken lines and the range of soil moisture in percentages of the dry weight of the soil by graphs with the weekly intervals as abscissas; while the ordinates represent the percentage of soil moisture present at the weekly determinations. Throughout the diagrams the vertical scale is denoted by figures at the left; and heavy lines are used for the determinations at 7.5 cm., and light lines for 25 cm. depth. The intervals between the graphs and the line denoting the wilting coefficient give the amount of the growth-water.

RANGE IN THE DIFFERENT ASSOCIATIONS

An examination of the accompanying diagrams will show at a glance some of the peculiarities of the water supply of the various associations. The results for the cottonwood dune association for 1911 have already been published (**18**), and show rather surprising results (fig. 16). The water content is rather constant, but seldom more than 5 per cent, a decidedly small amount. However, the wilting coefficient was here found to be less than 1 per cent, the average for many determinations by the indirect method being 0.8 per cent at both depths, the absence of humus and the instability of the soil accounting for the same coefficient at both depths. Considered in relation to this wilting coefficient, the soil moisture is seen to be continually at least twice the amount of water necessary for the growth of such a plant as wheat. This is in striking contrast to the desert-like aspect of this association, due to the almost complete absence of herbaceous undergrowth. Doubtless this constancy in soil moisture is largely due to the conserving action of a dry mulch of 3 to 5 cm. thickness maintained by the action of the wind upon the sand and to the small quantities withdrawn by the sparse vegetation. The record for 1912 (fig. 17) differs in no

important particular from that of the previous year, an unfailing supply of growth-water being maintained, although its average amount during the weeks of midsummer is slightly less.

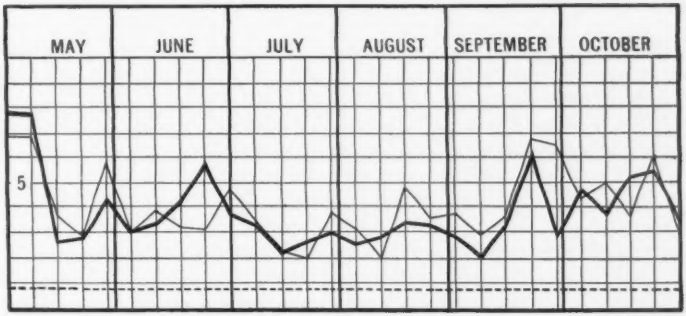

FIG. 16.—Graphs showing the range of soil moisture in the cottonwood dune for 1911; the heavy line at 7.5 cm. and the light line at 25 cm. depth; wilting coefficient represented by a broken line.

In the next association, the pine dune, the accumulation of humus increases the wilting coefficient to 1.1 per cent at 7.5 cm.,

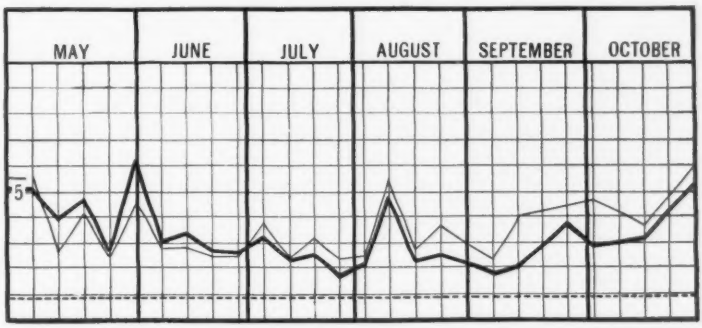

FIG. 17.—Graphs showing the range of soil moisture in the cottonwood dune for 1912; the heavy line at 7.5 cm. and the light line at 25 cm. depth; wilting coefficient represented by a broken line.

and to 1.0 per cent at 25 cm. The range of the moisture throughout both 1911 (fig. 18) and 1912 (fig. 19) is more irregular than in the previous association, especially in the upper stratum, and what

is more important, during three different weeks of each year the supply falls almost to or actually below the wilting coefficient. It is thus an association in which the growth-water fails repeatedly, and consequently with respect to its water supply is decidedly more

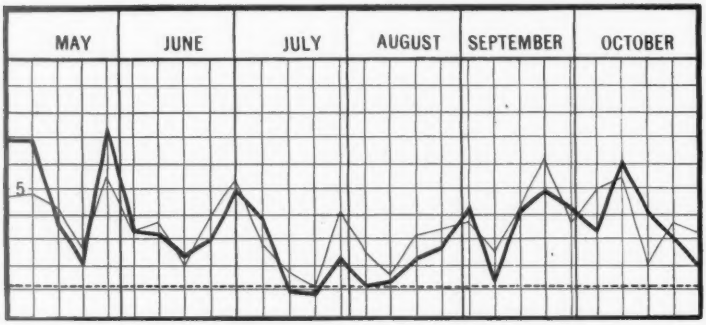

FIG. 18.—Graphs showing the range of soil moisture in the pine dune for 1911; the heavy line at 7.5 cm. and the light line at 25 cm. depth; wilting coefficient represented by broken lines.

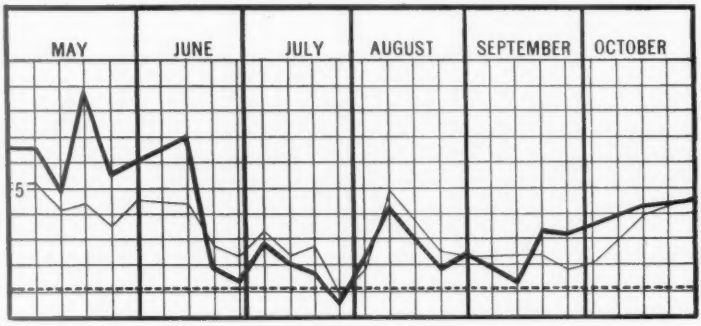

FIG. 19.—Graphs showing the range of soil moisture in the pine dune for 1912; the heavy line at 7.5 cm. and the light line at 25 cm. depth; wilting coefficient represented by broken lines.

xerophytic than the cottonwood dune. Reasons for the failure of the water supply may be found in the comparative absence of the conserving mulch of dry non-conducting soil, and in the much larger demands made by the denser stand of vegetation. The plentiful

supply during the weeks of spring permits the growth of a mesophytic herbaceous spring flora.

The open character of the forest on the oak dunes has brought no increase of humus, as indicated by wilting coefficients of 1.1 per

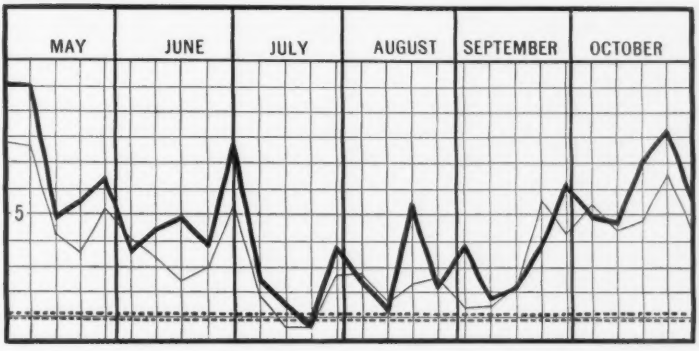

FIG. 20.—Graphs showing the range of soil moisture in the oak dune for 1911; the heavy line at 7.5 cm. and the light line at 25 cm. depth; wilting coefficients represented by broken lines.

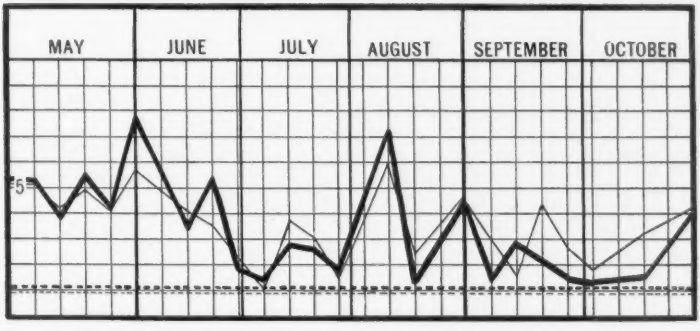

FIG. 21.—Graphs showing the range of soil moisture in the oak dune for 1912; the heavy line at 7.5 cm. and the light line at 25 cm. depth; wilting coefficients represented by broken lines.

cent and 0.9 per cent respectively for the 7.5 cm. and 25 cm. strata. The seasonal range of soil moisture is irregular (figs. 20, 21), and several times each season it approximates or falls below the wilting coefficients. The graphs indicate comparatively xerophytic

soil conditions approximately similar to those of the preceding association.

The results for the oak-hickory forest for 1911 have already been published (10), but are reproduced here for the sake of completeness, especially since the record for 1912, owing to a series of interruptions and accidents, is too fragmentary to be of any value. The soil here is a clay with an admixture of gravel, and differs in a striking manner from the sand in its moisture-holding capacity, shown by wilting coefficients of 9 per cent and 9.5 per cent at

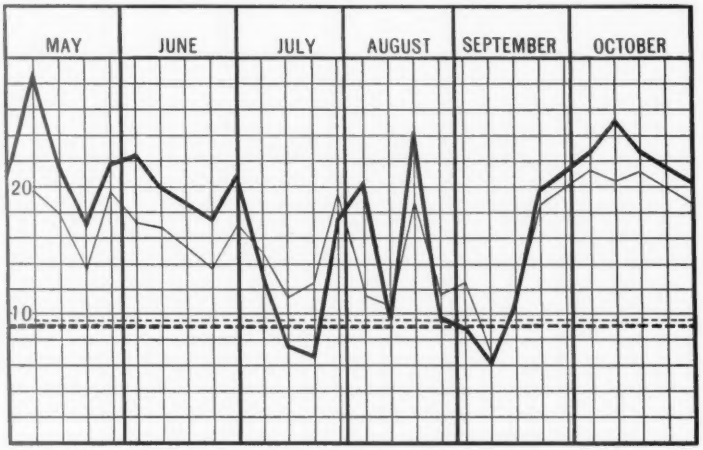

FIG. 22.—Graphs showing the range of soil moisture in the oak-hickory forest for 1911; the heavy line at 7.5 cm. and the light line at 25 cm. depth; wilting coefficients represented by broken lines.

depths of 7.5 cm. and 25 cm. The fluctuations in the soil moisture are great, particularly at 7.5 cm. (fig. 22). Although the water content of the soil at 35 cm. once falls below the wilting coefficient, the average amount of growth-water for the midsummer weeks is considerable (table III), much greater in fact than in any preceding association, indicating decidedly more mesophytic soil conditions.

It may be noted that the wilting coefficients now given for this and the succeeding association differ slightly from those formerly published. This is due to their redetermination by more careful methods, particularly to the use of the indirect method.

The ravine of the oak-hickory forest, with its abundance of humus, gave wilting coefficients of 16.3 per cent and 12.2 per cent

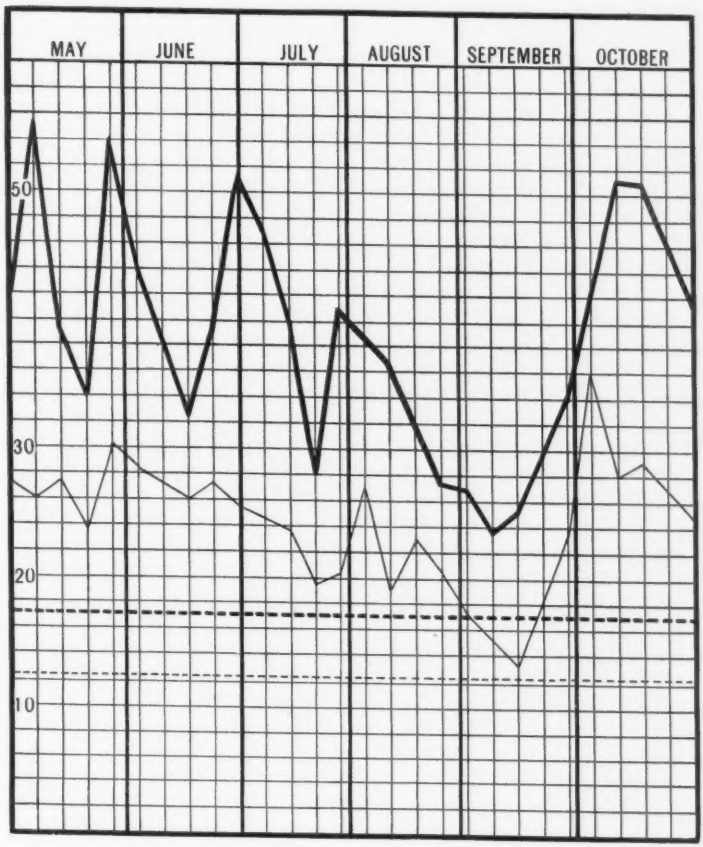

FIG. 23.—Graphs showing the range of soil moisture in the ravine of the oak-hickory forest for 1911; the heavy line at 7.5 cm. and the light line at 25 cm. depth; wilting coefficient represented by broken lines.

respectively for the soil at depths of 7.5 cm. and 25 cm. The graphs (fig. 23) show the presence of a constant and abundant supply of growth-water throughout the season. This would quite agree with

the hyper-mesophytism of rich floodplains, of which this may be regarded as a type.

The climax beech-maple forest shows the accumulation of humus in its wilting coefficient of 9.5 per cent at 25 cm., being increased to 13.5 per cent at 7.5 cm. In this association the soil moisture determinations were made only every second week, but the graphs (figs. 24, 25) show a constant and generous supply of

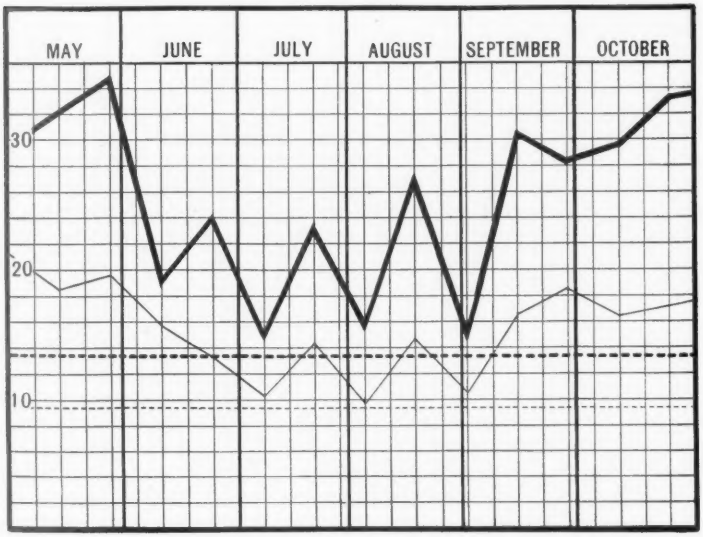

FIG. 24.—Graphs showing the range of soil moisture in the beech-maple forest for 1911; the heavy line at 7.5 cm. and the light line at 25 cm. depth; wilting coefficients represented by broken lines.

growth-water, indicative of truly mesophytic conditions. The supply of growth-water is unfailing. As in the other associations, the upper stratum shows the larger amount of variation. A comparison of the two seasons will show that, while the averages are about the same, the year 1912 shows a much greater uniformity in the range of the moisture supply.

The results for the prairie association are more difficult to interpret. The range plotted in fig. 26 is the mean of the two stations

reported by HARVEY (13) for the season of 1911, while fig. 27 gives the results obtained by Miss NEWLON in 1912. The wilting coefficients of 24 per cent at 7.5 cm. and 21 per cent at 25 cm. indicate soil with a high water-retaining capacity. This soil is at or near saturation point early in the spring, just as the growing season begins (figs. 26, 27); in fact it seems probable that the amount of water present is not only in excess of all requirements of the

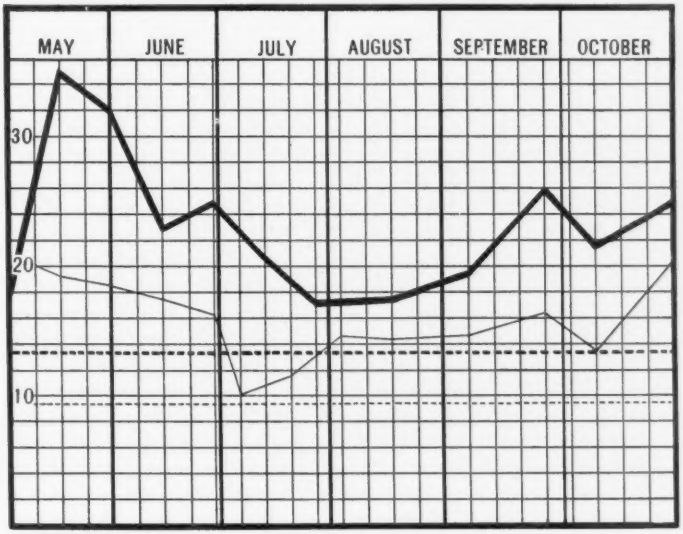

FIG. 25.—Graphs showing the range of soil moisture in the beech-maple forest for 1912; the heavy line at 7.5 cm. and the light line at 25 cm. depth; wilting coefficients represented by broken lines.

vegetation, but even in such abundance as to prove detrimental to many plants. Late in the fall the supply is also very large. In striking contrast is the small and irregular supply during midsummer, when the wilting coefficient is more than once reached or approximated. In general the habitat is shown to be one of extreme fluctuations in respect to its moisture supply, conditions which may help to account for the absence of trees. It is particularly xerophytic during late summer.

GENERAL CONCLUSIONS

An examination of all the graphs showing the range of soil moisture, as well as a general consideration of the conditions of growth

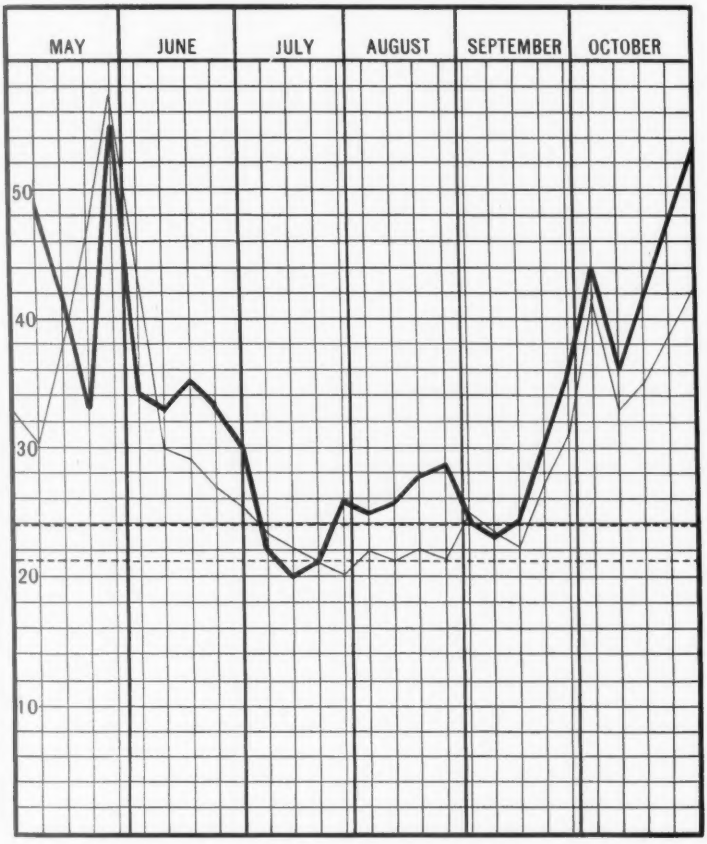

FIG. 26.—Graphs showing the average range of the soil moisture in the edaphic prairie for 1911; the heavy line at 7.5 cm. and the light line at 25 cm. depth; wilting coefficients represented by broken lines (after HARVEY).

in these associations, indicates that only during midsummer is there any scarcity in the supply in any of the habitats. It has seemed desirable, therefore, and even more necessary than in the evapora-

tion studies, to limit our comparisons to this period of stress, and to establish the rather arbitrary limit of the 10 weeks from the last of June to the first of September. A summary for these weeks appears in table III.

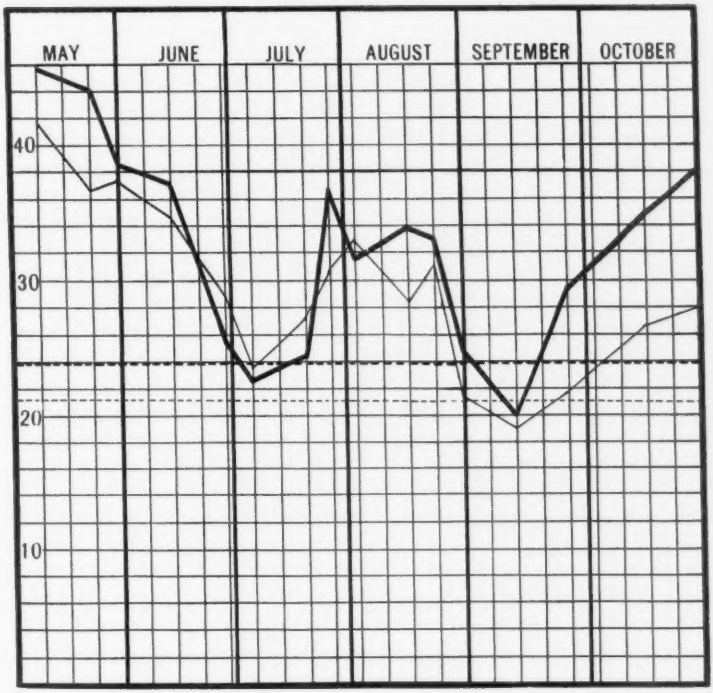

FIG. 27.—Graphs showing the range of soil moisture in the edaphic prairie for 1912; the heavy line at 7.5 cm. and the light line at 25 cm. depth; wilting coefficients represented by broken lines.

No one can realize more fully than does the writer the limitations of the data or the desirability of having them supplemented by more numerous determinations, especially from deeper strata. These limitations will make the conclusions more or less provisional and subject to modification and correction in the future. The most interesting and profitable comparisons are doubtless those to be made from a consideration of the growth-water data shown

in table III, and especially as expressed in the sixth and seventh columns, which contain the mean percentages of growth-water and the comparative amounts, the beech-maple forest being taken as a standard and its mean growth-water represented by 100. In the five associations that form the succession, the mean growth-water for midsummer of the two seasons will be found, if we except the cottonwood dune, to form a progressive series, the most mesophytic association having the largest amount. This was exactly what was supposed to be the situation, but hitherto no quantitative data of such moisture relationships have been available, and it has been

TABLE III

WILTING COEFFICIENTS AND MEAN PERCENTAGES OF GROWTH-WATER IN THE VARIOUS ASSOCIATIONS DURING THE 10 MIDSUMMER WEEKS OF 1911–1912

ASSOCIATION	DEPTH IN CM.	WILTING COEFFICIENT	GROWTH-WATER				RATIO BETWEEN EVAPORATION AND GROWTH-WATER
			1911	1912	Mean	Comparative am'ts	
			per cent	per cent	per cent	per cent	
Cottonwood dune..	7.5	0.80	2.2	1.8	2.15	49	11.7
	25.0	0.80	2.6	2.0			
Pine dune.....	7.5	1.10	0.9	0.7	1.15	26	10.7
	25.0	1.00	1.7	1.3			
Oak dune.....	7.5	1.10	1.4	1.4	1.27	29	9.37
	25.0	0.90	0.8	1.5			
Oak-hickory.....	7.5	9.0	3.2	.....	3.3	75	2.78
	25.0	9.5	3.3	.....			
Beech-maple.....	7.5	13.5	5.5	5.0	4.4	100	1.81
	25.0	9.5	3.0	4.0			
Prairie.....	7.5	24.0	4.0	4.0	4.7	107	2.91
	25.0	21.0	4.9	5.9			

impossible to tell how much an association differs in its water conditions from the preceding or succeeding association. As has already been stated, the cottonwood dune, with a larger and more constant water supply than the two succeeding associations, must owe its surplus to the conserving power of its dust mulch and to the small outgo due to the paucity of its vegetation.

The comparative amounts of growth-water indicate even more clearly the relationship existing between the available water supply of the associations, and should serve to emphasize the fact that the progressive increase in the water-retaining power of the

soil, due largely to its increased humus content, must play no inconsiderable rôle in causing the succession here culminating in the mesophytic beech-maple forest. Little need be said concerning the rank of the prairie, in respect to its soil moisture in comparison with the other associations under consideration, further than to point out that its soil has a very great water capacity, and that over against its large amount of growth-water should be placed the fact that the supply completely fails at intervals. More investigation must be made before more definite comparisons can be made.

Another and still more important comparison may be instituted among the associations under investigation by considering the ratio between the average mean weekly evaporation rates for the 10 midsummer weeks of the years 1910–1912 and the mean growth-water for the same period. These ratios are expressed in the final column of table III. In determining these ratios it is recognized that the units of measurement in the case of the evaporation rates and the soil moisture are not directly comparable. Still it is thought that the comparison is a legitimate one, and institutes a quantitative summation of the mesophytism of the habitats which is valuable and exceeds in accuracy anything hitherto attained. It is true that these habitats are limited to the lower stratum of the aerial and the upper strata of the subterranean vegetation, but, as previously pointed out, these are the portions of the habitat that are of critical importance in the establishment and maintenance of the associations, because in them the seedlings, both woody and herbaceous, develop. An extension of the habitats by the addition of the higher strata of the air and the lower strata of the soil containing all the aerial and subterranean portions of the vegetation would doubtless modify and perhaps decrease the steepness of the gradient between the various ratios. The ratios may either be compared directly, remembering that the mesophytism of the various habitats varies in inverse ratio with the numbers expressing these ratios, or the beech-maple forest may again be taken as the standard and represented by 100, when the direct ratio of the mesophytism of the corresponding portions of the oak-hickory forest, the oak dune, the pine dune, and the cottonwood dune will be respectively 65, 20, 17, and 15. The prairie expressed in similar terms will be 62. These

comparative values of the moisture factors show such a surprising rate of increase as one proceeds from the pioneer to the climax associations that it cannot be doubted that such a change in water conditions must be one of the chief factors, if not the most important cause, of the succession of associations from the more xerophytic to the more mesophytic.

Summary

1. These data represent the evaporation rates in the lower aerial stratum and the range of soil moisture in the upper subterranean strata of the vegetation of the various associations, but these must be regarded as critical regions, since within them develop the seedlings which determine the character of succeeding vegetation.

2. Evaporation at different stations in the same plant association exhibits variations similar in character and degree.

3. The rate of evaporation in the cottonwood dune association, both by its great amount and by its excessive variation, seems a quite sufficient cause for the xerophytic character of the vegetation and for the absence of undergrowth, in spite of the constant presence of growth-water.

4. The pine and oak dune associations resemble one another closely both in their mean evaporation rates and in their supply of growth-water. The former is slightly more xerophytic during the midsummer weeks.

5. The vernal vegetation of the pine dune is quite as mesophytic as that of the succeeding association, thus agreeing with its lower evaporation rate during that portion of the year.

6. The evaporation rates and the amount of growth-water in the various associations vary directly with the order of their occurrence in the succession, the pioneer being the most xerophytic in both respects.

7. The ratios between evaporation and growth-water in the beech-maple forest, oak-hickory forest, oak dune, pine dune, and cottonwood dune associations have been shown to have comparative values of 100, 65, 20, 17, and 15 respectively, and the differences thus indicated are sufficient to be efficient factors in causing suc-

cession. The corresponding value of this ratio in the prairie association is 62.

8. The midsummer conditions of the prairie association seem to be decidedly xerophytic.

Grateful acknowledgment is made of the cooperation and advice given by Professor HENRY C. COWLES, under whose direction the investigation has been conducted, and of the assistance of Messrs. WADE MCNUTT, E. M. HARVEY, C. SHIRK, and Miss L. NEWLON in collecting data.

UNIVERSITY OF CHICAGO

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ON CERTAIN PECULIAR FUNGUS-PARASITES OF LIVING INSECTS[1]

ROLAND THAXTER

(WITH PLATES XVI–XIX)

During the past ten years the writer has examined many thousands of freshly collected insects of various sorts preserved in alcohol, which have come from various parts of the world, especially from tropical regions, and in looking them over for fungus-parasites, the possibility of encountering forms which might throw some light on the origin of the Laboulbeniales, yet not members of this group, has been constantly in mind. Although the hope of meeting with forms of this nature has not been realized, and nothing remotely related to these plants has been seen, apart from many genera and species which are entirely typical of the group, a certain number of wholly unrelated fungi have been observed, which appear to be as peculiar in their mode of life on living insects as are the Laboulbeniales themselves. Although few in numbers, these parasites belong to several quite unrelated groups, and seem to have adjusted themselves successfully to the uncertain conditions of life and propagation on rapidly moving living hosts. The apparent rarity of most of them seems quite remarkable, however, in view of the fact that any such exist; since, if a certain small number of insects furnish favorable conditions for such development, it is difficult to understand why hosts of other similar insects have not also been similarly parasitized, and why an extensive flora of this nature, or at least one comparable in numerical importance to that of the Laboulbeniales, has not been developed.

What may be called the idiosyncracies of such parasitism are well illustrated by equally inexplicable host relations or rather lack of host relations, between certain groups of insects and the Laboulbeniales. The ants, for example, would seem from their

[1] Contributions from the Cryptogamic Laboratories of Harvard University, LXXIV.

enormous numbers, gregarious habits, wide distribution, overlapping generations, and usual habitats, to offer the most favorable conditions for the development of a very large flora, but as yet only two forms of Laboulbeniales have been found on them. Their habit of cleaning themselves evidently does not interfere with the successful propagation of such parasites, since several typical genera and species are thus successfully attacked. That they rarely become hosts, however, seems to be indicated by the fact that, among the many that have been examined both by the writer and by Professor WHEELER, whose attention has been called to this matter for some years past, none have been found which appear to be hosts for any forms except the common *Laboulbenia formicarum* of America, and the apparently equally common *Rickia Wasmanni* of Europe. On the other hand, the most nondescript type among those described below is an ant-parasite; although its characteristics are not such as would have been expected to makes its parasitism successful on any type of insect.

Of the five genera herewith enumerated, three, including the form on ants just mentioned, are very closely allied to well known genera of Hyphomycetes, the species of which are either saprophytes or parasites on other plants; and did they not occur on living hosts, might have been regarded as accidental saprophytes which had developed after death; dead insect remains being, as is well known, a very prolific source of such forms. Since, however, all the insects examined in the present connection were collected while living, directly into alcohol, and some were examined by the writer while still alive, there can, it would seem, be no question as to the true nature of the relation in these instances. Of the two remaining genera, one comprises species also belonging to the Hyphomycetes, but not closely related to any described types, while the other seems to be more nearly related to the Chytridiales than to other known organisms.

In comparing the miscellaneous assemblage of forms which are now known to live as external parasites on living insects, it is of interest to note that a great majority, at least, possess one characteristic in common, namely a more or less clearly defined, blackened footlike structure which serves both as an organ of

attachment to the host and a means of absorbing such materials as are necessary for growth. In other words, the foot is also a haustorium. Among the Laboulbeniales, those forms which, like *Dimeromyces rhizophorus*, perforate the host's integument, may be assumed to derive their nutriment directly from the fluid materials which surround their deeply penetrating rhizoids; in fact this conclusion seems unavoidable. But that a very closely allied species like *D. coarctatus*, which possesses a typical foot and does not penetrate, although it grows under identical conditions on a soft-bodied host, should use materials which are either of a different nature or derived from a different source, seems not at all probable. In the opinion of the writer, even those forms which grow on spines or hairs or thin wing-membranes obtain their food supply from the same source as do the penetrating forms, namely from the circulatory system, which by diffusion or otherwise supplies the structures mentioned in the living insect. There seem certainly to be no differences in the vegetative characteristics or in the peculiar fatty cell contents in any of the Laboulbeniales which would suggest that the nutrition of these plants is not the same in all cases. The assumption that the food material is obtained directly from the circulation seems further supported by the fact that individuals which grow nearer the circulatory centers, as for example about the bases of the two anterior pairs of legs, or along the chief circulatory channels, are usually larger and more luxuriant. That any considerable portion of their food is derived from the integument itself seems quite improbable in view of the host-relations of the penetrating forms. An examination of the accompanying plates will show the presence, in most instances, of a blackened footlike structure similar in a general way to that of the Laboulbeniales, and in the writers' opinion these plants, also, may be assumed to obtain their food materials from the circulatory system through the medium of this haustorium.

Among entomogenous Fungi Imperfecti, one other type has been observed on living insects, which is not herewith included; for the reason that, as yet, no definite spore-formation has been seen in any of the several species examined. These plants consist of colorless, septate, copiously branching filaments, which grow

on various parts of small silphids, especially, and on the wings of certain flies in the tropics. They may produce conspicuous and dense tufts, and in some instances correspond very closely in external form to types of *Cladophora*. No characteristic foot is developed and no definite spores have been seen, propagation being effected, as far as can be determined, solely by fragmentation.

Hormiscium myrmecophilum, nov. sp.—Plate XIX, figs. 22–25

Filaments nearly hyaline becoming brownish, darker near the base, closely septate, the cells often as broad as, or broader than long, undifferentiated, distally bluntly rounded, erect or curved upward, rigid, simple, less frequently sparingly branched, tapering but slightly if at all, one to several arising from a deeply blackened foot of variable size and shape. Maximum length about 280 μ by 7–8 μ in width.

On various parts of *Pseudomyrmex* sp., Amazon (MANN).

This plant was received from Mr. W. H. MANN, who found it growing on a majority of the individuals taken from a nest of *Pseudomyrmex*, while he was acting as entomologist of the Leland Stanford Expedition to Brazil in 1911. It is sufficiently large to be readily visible as it projects from the surface of the host, and, although it is such an insignificant type, possesses sufficient individuality to distinguish it. It produces no definite spores or differentiated cell-groups, as far as has been observed, and appears to propagate itself by fragmentation only, the filaments proliferating, as indicated in the figures, after a terminal portion has been broken off. The opaque and somewhat variable "foot," by which the individuals are attached to the surface of the host, appears to correspond to such a small fragment broken from a hypha, which, adhering laterally, becomes blackened and indurated, and gives rise to new filaments, while at the same time it serves the office of attachment as well as of food absorption. It is not, however, so firmly fixed as is the case with most of the Laboulbeniales, and might be easily removed by its host from portions of the body which can be reached by the mouth. When one considers the habits of cleanliness which characterize most ants, it seems singular that

a type like the present should be able to establish itself successfully. It is possible that an examination of fresh specimens might show the presence of some more or less viscous secretion from the hyphae, which enables them to adhere readily and firmly to any surface with which they may come in contact, but there seems to be no indication that such is the case in the alcoholic material.

It may here be mentioned that several other imperfect forms have been seen on ants. Among them one has been found by the writer in the vicinity of Cambridge, which forms blackish incrustations on various parts of the host and gives rise to a few short, colorless, erect branches. It has not been possible, however, to determine the nature of this plant. Another form has recently been mentioned by Dr. BISCHOFF (Berl. Ent. Zeitschr. 57:(2), 1912), as occurring on living ants at Potsdam, which possesses brown hyphae and grows on various parts of the host in tufts. No further details as to its structure are given, and it is uncertain whether it is related to the present form.

Muiogone, nov. gen.

Entomophilous; pulvinate. Sporophores short, simple, hyaline, crowded. Spores terminal, solitary, dark, muriform, the cells of the mid-region distinguished from those of the basal and terminal portions, which bear more or less conspicuous median processes or spines.

Muiogone Chromopteri, nov. sp.—Plate XVI, figs. 1–3

Sporophores short, slender, several-septate, crowded so that the spores form a compact spreading pulvinate mass on the surface of the host. Spores irregularly oblong or piriform, usually broader distally and tapering slightly at the base; the cells very numerous and arranged in about twelve tiers which are regular, except distally; four or five of the middle tiers remaining subhyaline or variably suffused with dirty brownish yellow; contrasting, though not abruptly, with the nearly opaque blackish brown basal and terminal regions; the cells of the latter more prominent, forming a sort of cap; all of them, especially the upper which are slightly irregular, usually slightly flattened distally, and bearing a spine-

like process, straight or curved, sometimes stouter and distally perforate, sometimes obsolete: the cells of the basal tiers similarly modified, less prominent, flattened; the spinous process minute or obsolete. The whole sporiferous pustule, in the type, 330 μ in diameter by 210 μ deep. Spores 62–77×32 μ, the stalk (broken) about 25×7 μ.

On the inferior surface of the abdomen of *Chromopterus delicatulum* Beck., Kamerun, West Africa.

A single specimen of the apparently rare host, bearing this very peculiar fungus on its abdomen, was found in a collection of flies sent me by the Rev. GEORGE SCHWAB, to whom I am very greatly indebted for this as well as for numerous similar favors, and to whom I owe the remaining forms from Kamerun described below. Since there is but a single specimen, I have been unwilling to destroy it in order to determine the exact relation of the fungus to its host, and have merely removed a certain number of spores with a needle point from the general mass, which is firmly adherent to the soft integument of the inferior surface of the abdomen. This mass is somewhat diagrammatically illustrated in fig. 1, where it is shown *in situ* on the insect's body; but whether the vegetative hyphae penetrate the integument, or merely adhere firmly to its surface, cannot be determined in its present condition. The spores (fig. 2), which are in different stages of development in different parts of the mass, the younger ones mostly near the edges close to the substratum, are easily detached, and carry with them a portion of the slender stalk, which is probably somewhat longer than is represented in the figures. The cap-cells of the spore are distinctly different from those of the paler mid-region, and their terminal processes vary greatly in development. In some instances (fig. 3) they are much stouter, and seem certainly to be distally perforate; although in others this is quite evidently not the case, and it is barely possible that they may be associated with some viscous secretion which might aid the spore in attaching itself to a new host. No such secretion, however, can be detected in the present condition of the material; although, as in the case of the *Hormiscium* just described, as well as in the species of the following genus, it is difficult to imagine how the parasitism of such forms

can be successful in the absence of some contrivance to insure adherence to a moving host. The cells of the lower tiers of the spore, though more prominent than the smaller ones of the middle region, are distinctly flattened, and the minute apical projection, when present, can only be distinguished along the margin.

The genus is perhaps too near *Sporidesmium*, and I have had some hesitation in separating it under a new name. The differentiation of its spores, however, into specialized distal, basal, and middle regions, of which the last is probably the functional portion, corresponds in a general way to that seen in the spores of the following genus, and, taken in connection with its entomogenous habit, may perhaps be considered as sufficient reason for regarding it as distinct. It seems not improbable that the sporiferous pustule arises from the multiple germination of the paler mid-region of the spore, which must include nearly one hundred cells, in some cases.

Muiaria, nov. gen.

Entomophilous, more or less deeply suffused throughout, growing in dense, more or less isolated tufts, or rarely repent, each tuft attached by a blackened base in which the vegetative hyphae may be indistinguishable; the tufts consisting of fertile, or both sterile and fertile elements; the sterile, when present, simple and not clearly distinguished from the sporophores; the latter bearing terminally solitary spores which are not abjointed, or, as a rule, clearly differentiated from them. Spores at first transversely septate, consisting of a slender terminal portion and a broader main body in which two flat central cells are distinguished that become several times longitudinally divided, after usually dividing once transversely; the cells adjacent to these four central tiers often showing occasional longitudinal or slightly oblique divisions; the stalk and distal prolongation sometimes producing a short but characteristic spurlike process.

This genus, which inhabits living flies in the tropics, so closely resembles certain types of *Macrosporium* that, as in the case of *Muiogone*, I have hesitated to give it a new name. It seems, however, to possess certain peculiarities, in addition to its very different habit of life, which are sufficiently distinctive to render

a generic separation desirable. In only one species, *M. repens*, does it assume a repent habit, such as is illustrated in fig. 6, and in this instance only on the host's wing. This may be due in part to the less nutritious character of the substratum; yet other species, when they occur in the same situation, retain their isolated tuft-like habit, which is also characteristic of this species when it occurs on the body or legs of its host (fig. 8).

The spores, which always resemble those of *Alternaria* in general form, differ from those of *Macrosporium* in being inseparable from the sporophore, a portion of which breaks off with them, and in the characteristic differentiation of the central portion, which consists of two similar flattened cells; which, in all the species except *M. repens*, become divided once transversely before the appearance of a few longitudinal septa. The four tiers of small cells which result are usually clearly distinguishable, as is indicated in fig. 4; and with the exception of *M. repens*, the vegetative portion is hardly developed; a tuft of more or less divergent elements being attached by a compact blackened base, which may or may not be associated with slight rhizoid-like outgrowths. The body of the spore is flattened, so that when it is viewed edgewise, it is often hardly broader than the stalk and tip. Both the spores and their stalks are brittle, and it seems probable from the appearance of very small plants which are sometimes found growing on hairs or spines, that propagation may be effected by small detached fragments as well as by whole spores, from which the larger groups appear to arise; although in the latter case, it is seldom possible to determine definitely that a portion of the general blackened base is made up of the old spore body. The spurlike processes which may arise in some species (figs. 9), either from the stalk just below the spore, or from the slender termination of the latter, sometimes in both positions (figs. 4 and 5), are characteristic, but are not present invariably or in all the species.

The body of the spore, sometimes also its termination and the whole or a portion of the stalk and sterile elements, if they are present, are irregularly mottled or lined by a somewhat darker incrustation which gives the surface a somewhat roughened appearance. This superficial modification tends to obliterate the longi-

tudinal divisions of the cells when they occur, so that they often cannot be clearly distinguished without the use of an immersion.

It is evident from an examination of the sporophores, that after a spore has matured and has broken off, the portion of the stalk which remains proliferates distally and produces a new spore. Since this may be repeated several times, the spore-formation in a given tuft may be more or less continuous, even if new sporophores are not produced.

Although the species of this genus, all of which occur on living individuals of small flies, are so unlike other entomogenous types, they appear to be similarly limited to definite hosts. This seems to be very distinctly the case, for example, in *M. repens*, which has been seen on numerous individuals all belonging to a single species, apparently, of the genus *Clasiopa*, while no others among the very numerous and often closely related flies, which were collected with them in the same locality, are thus parasitized.

In addition to the species described below, a few others are known, but from lack of sufficient material these are not herewith included.

Muiaria gracilis, nov. sp.—Plate XVII, figs. 12–13

Olivaceous, forming a tuft attached by a compact, footlike, blackened base. Spores and sporophores very long and slender; the body of the spore not abruptly distinguished from its long terminal portion, or from the sporophore; the cells of the four central tiers very small; the adjacent cells above and below usually undivided by longitudinal septa; the whole rather inconspicuously marked by more or less elongated darker areas separated by lighter somewhat labyrinthine lines, this modification involving the upper portion of the sporophore and the lower two-thirds, or more, of the slender spore-termination; the spore outline even, with hardly indicated indentations at the septa or with none. Total length of spore and stalk 300–480 μ, the stalk about 7 μ in diameter, the body of the spore 14–17 μ in diameter.

On the legs and inferior surface of the abdomen of *Leucophenga* sp., no. 2299, Kamerun, West Africa (SCHWAB).

This species is well distinguished by its very slender form and the great length of its spores and sporophores. In one or two of the tufts it seems possible to distinguish the body of the spores, from the middle segments of which they seem to have arisen, lying flat against the substratum.

Muiara Lonchaeana, nov. sp.—Plate XVII, figs. 10–11

Scaly-punctate throughout, or almost hirsute. Sterile and fertile elements relatively rather short and stout, densely crowded; the sterile elements numerous. Basal cell of the spore usually rather abruptly distinguished from the sporophore, which is often shorter than the spore itself; the body of which is irregular, its basal and distal cells variably inflated and constricted at the septa, rarely divided longitudinally. Spores 100–140×15–18 μ, the stalk 35–70×8 μ.

On the abdomen, legs, and antennae of *Lonchaea* sp., no. 2298, Kamerun, West Africa (SCHWAB).

This species is characterized by its dense habit of growth, dark color, conspicuously and coarsely scaly-punctate spores, which are more irregular in outline than those of the other species, and are borne on relatively short stalks. The sterile elements are more than usually numerous and are roughened much like the spores. In certain instances small groups have been observed which seem certainly not to have sprung from entire spores, but rather from small fragments. Two specimens of the host were found to be parasitized.

Muiaria armata, nov. sp.—Plate XVI, figs. 4–5

Forming a compact tuft with narrow base. The stalk and spore-termination pale, relatively slender and rather abruptly distinguished from the body of the spore; which is relatively broad, rather rich brown, the four middle tiers clearly distinguished; the cells immediately above and below divided by occasional longitudinal septa; the outline comparatively even, and streaked in a somewhat labyrinthine fashion by darker crustlike areas, which are wholly absent on the stalk and distal portion of the spore; either or both

of which may be furnished with a simple, usually somewhat recurved spurlike outgrowth which may, however, be wholly wanting. The sterile elements scanty. Total length of stalk and spore 210—260 μ; average length of spore to tip 120 μ; body of spore 60×18–24 μ, the termination 3.5–4 μ broad. Spur from spore-tip about 20×4 μ, that from the stalk somewhat longer.

On the legs of *Drosophila* sp., no. 2178, Sarawak, Borneo.

This very distinct form was found among material for which I am greatly indebted to the kindness of Mr. J. C. MOULTON, and has been seen on a single specimen only of its host. It is clearly distinguished by the relatively broad and evenly curved outline of the body of its spores, their characteristic markings, relatively slender termination, and by the peculiar spurlike processes, which may arise from the latter, as well as distally from the sporophore, or may be wholly absent.

Muiaria repens, nov. sp.—Plate XVII, figs. 6–9

Repent on the wings or growing in tufts on other parts of the host; brown, concolorous. Repent form producing rather closely septate, somewhat tortuous hyphae, tending to run in straight lines, sparingly branched, bearing solitary spores here and there, or small groups of spores along the anterior wing margins or along the larger veins. The spores in both types rather short and stout; the two middle tiers not transversely divided; the cells above and below them similar, or hardly distinguishable, and showing several longitudinal septa; the stalks somewhat shorter than the spore, as a rule, and usually bearing a subterminal spurlike process. Sterile elements not distinguished. Spores 60–70×15 μ, those on the wings somewhat smaller. Total length including stalk 70–100 μ.

On the wings and abdomen of *Clasiopa* sp., no. 2283, Kamerun, West Africa (SCHWAB).

This species is unlike those previously described from the fact that the four tiers of small cells, usually present in the middle of the spore body, are replaced by two tiers of relatively larger cells, which are often so similar to the cells immediately above and

below, that they are hardly differentiated from them. This appears to be due to the fact that the two median flattened cells from which these tiers are formed do not divide transversely, as in the other species, before the longitudinal septa appear. In one group, a portion of which is represented in fig. 8, the spores have begun to germinate *in situ*, and it is noticeable that the rhizoid-like germ tubes all arise from cells of the middle region. Although other species have been found growing on the wings of flies, it is only in the present instance that a creeping series of hyphae is produced, in place of the usual compact tuft. This repent habit seems therefore to be specific. The species seems to be distinctly limited to a single host, of which perhaps two dozen have been found infested, and here it may be remarked that the species of *Stigmatomyces*, which inhabits the same insect, was found to occur much more rarely. It is thus evident that, however unsuited such a form as the present may seem to its parasitic habit, it is actually quite as successful as the *Stigmatomyces*, which is so peculiarly adjusted to this mode of life.

Two other forms very closely allied and perhaps identical with this species, but less definitely repent and differing in minor points, have been examined on species of *Clasiopa* from Sarawak and from Trinidad; but sufficient material is not available for a definite determination in either case.

Chantransiopsis, nov. gen.

Entomophilous. Filaments firm, elastic, persistent, thick-walled, colorless, septate, growing in variably developed tufts attached to the body of the host by an opaque black base, or foot; variably branched; the terminal branches sterile or fertile, and bearing solitary terminal simple spores successively abjointed.

This type was first found growing on living specimens of the staphylinid beetle *Xantholinus* near Fresh Pond, in Cambridge, where scanty material, largely sterile, was obtained in the autumn of 1900 and 1902. Later, among a number of Javan beetles sent in alcohol by the late F. ROUYER, two more genera of staphylinids were found to be similarly infested, as well as a third species belonging to the Hydrophilidae. Although it has been sought for on

thousands of other insects belonging to these families which have been examined, this type has not again been seen, and must thus be assumed to be very rare or local. Having in mind their possible floridean derivation, it was at first thought that this type might prove to be connected with some genus of the Laboulbeniales, and to represent a form corresponding in some manner to the monospore-producing *Chantransia*-forms among the Rhodophyceae, the general habit of the plant and its spores suggesting a resemblance of this nature. There seems to be not the most remote possibility, however, that such is actually the case. These plants are not associated with any forms of Laboulbeniales which might by any chance form part of their life cycle, and they have no inherent characteristics, except their similar habitat, which would point to such a connection.

The spores are, as a rule, rather sparingly produced, and at maturity the outer wall appears to be somewhat viscous or gelatinous, so that they may perhaps more readily adhere after being abjointed. In many instances, as is indicated in figs. 19 and 21, a collar is present below the developing spore, which seems to indicate that the usually somewhat smaller terminal cell of the fertile branch is proliferous, and continues to abjoint spores after the first has been separated. In this process the terminal cell enlarges, pushing upward, and soon divides by a partition coincident with the plane of separation of the first spore, which is indicated by a slight ridge or collar. The upper of these two cells becomes the new spore, and after it has been separated, the lower, renewing its activity, produces a third spore in a similar fashion, and so on.

The filaments are quite colorless and appear white on the living host. They may be simple, or several times branched, varying considerably in this respect. In one Javan species, not herein included, since it is sterile, a copious development of mostly unilateral branchlets takes place; some of the longer branchlets being elongate and attenuated, as well as spirally coiled at the tips. The filaments are also apt to be beset by masses of bacteria, and in some cases by attached infusoria. The spores usually contain one or more large fatty masses, and the contents of the cells are rather

coarsely granular-reticulate. The deep black foot is usually small and clearly distinguished. In *C. stipatus*, however, it forms a more extensive black crust, a portion of which, only, is shown in fig. 17, from which the crowded filaments arise in a mass. Three species are here distinguished, and there are one or two other Javan forms in the material at hand, which may prove to be distinct, and another from the Philippines.

Chantransiopsis decumbens, nov. sp.—Plate XVIII, figs. 19–21

Filaments divergent or decumbent, flexed or reflexed, colorless, rather scanty, long and slender, simple or once to several times branched, rather closely septate below the terminal sterile branchlets; which are more remotely septate and taper slightly to their blunt tips, which are very rarely more attenuated and slightly spiral. Spores long-elliptical or subpiriform, 30–35×9–11 μ. Total length of branches about 230 μ, the longest 350 μ, with an average diameter of about 6 μ.

On the inferior surface of an undetermined staphylinid beetle, Malang, Java (ROUYER).

This species differs from the others which have been examined by its more or less decumbent habit, some of the filaments lying in contact with the surface of the host. Its large spores are somewhat broader than those of the following species, from which it also differs in its small foot and spreading flexed and stouter filaments. The spores seem to be more frequently produced than in the other species.

Chantransiopsis stipatus, nov. sp.—Plate XVIII, figs 17–18

Filaments densely crowded; erect, straight, or but slightly flexed, rigid, hardly tapering, closely septate, usually once branched near the base; arising from a spreading opaque blackened insertion. Spores elongate, distally rounded, nearly isodiametric, or slightly broader in the middle, 25–32×8 μ. Filaments about 110×5 μ.

On the inferior surface of a staphylinid beetle allied to *Tachinus*, no. 1401, Java (ROYER).

This species differs from the preceding in its densely crowded, erect, nearly straight filaments, which seldom branch, except close to the base, and in its somewhat smaller, narrower spores. Its insertion is an opaque black crustlike structure, from which large numbers of filaments arise in a dense tuft. Only a portion of this crust is shown in the figure.

Chantransiopsis Xantholini, nov. sp.—Plate XVIII, figs. 14–16

Filaments somewhat densely tufted, sometimes rather copiously branched; erect, slightly flexed, arising from a small and well defined opaque black foot. Spores relatively small, ovoid to oblong, 10–18×5–6 μ. Filaments 70–175×5–7 μ.

On the inferior surface of the thorax of *Xantholinus obsidianus*, Fresh Pond, Cambridge.

This species is smaller in all respects than the two preceding forms. The outline of the successive cells tends to become slightly convex, and the spores are rather short and stout. The species has been collected but twice, in October 1900, and again in 1902 in the same locality; but although it has been repeatedly sought for elsewhere, it has not again been met with, and may be regarded as very rare.

A small tuft of a different species has also been observed on a species of *Xantholinus* from the Philippine Islands, but the specimen is not sufficient for description.

Amphoromorpha, nov. gen.

Entomophilous; consisting of two superposed cells surrounded by a firm common envelope, which becomes perforate at the apex for the escape of numerous naked amoeboid(?) spores into which the upper cell becomes completely divided; the base attached to the host by a well developed blackened foot.

The position of this genus is quite uncertain. It is known only in its fully mature condition, the characteristics of which seem to correspond more closely to those of some of the Mycochytridineae than of any other organisms. The spores, into which the upper of the two cells appears to divide *in toto*, seem to possess no walls,

and their irregular outline suggests that they may be amoeboid in character. No appearance has been seen which would suggest the presence of cilia. The lower cell is surrounded by a very thin membrane which, in a few specimens, is made visible through the shrinkage of the protoplasm; but no indication of this division can be seen in the general envelope, which is continuous from base to summit like that of the Laboulbeniales.

All the individuals examined are, as has been mentioned, quite mature, and the distal region is filled in every case with closely packed spores, except in the individual represented in fig. 28, from which the contents has for the most part escaped through a rupture at the base. It is therefore not possible to determine what the course of development is; whether, after the discharge has taken place the basal cell enlarges so as to fill the cavity, and again cuts off a terminal cell which divides as before, or whether there is but one such period of sporulation in the history of an individual. It is evident, however, from a comparison of different individuals, that the relative space occupied by the spore-mass and by the basal cell varies greatly, and it is not impossible that the original spore-mass may be pushed slowly out by pressure from the enlarging basal cell which, after it has filled the whole cavity, cuts off an upper portion which divides into spores that are again pushed out by the further growth of the cell below. Such a process would correspond very closely to that described, for example, in *Cladochytrium Alismatis* by CLINTON, in which, however, the successive sporangia empty completely through the swarming of the zoospores at the moment of maturity. Unless the spores of the present type are actively amoeboid, some mechanical means for emptying the sporangium, like that above suggested, seems necessary, since there is no indication that the spores are furnished with cilia.

In addition to the organism herewith described, several others have been noticed that appear to be similar in their general characters. One of these is clavate in shape, much smaller than the present form, and is found occasionally on Carabidae or on Laboulbeniae growing on these hosts in New England, but of this no material is at the moment available. A second type occurs commonly on a variety of insects and rarely on Laboulbeniae infesting

them, and is represented in figs. 30–31. That these organisms belong to the same category seems very probable; but since their development has not as yet been satisfactorily followed out, these figures are given merely to call attention to their existence. They usually grow on the bristles, antennae, or legs of their hosts, and closely resemble germinating spores of Laboulbeniales, or might be mistaken, when mature, for male individuals of Amorphomyces or Dimeromyces. There is no reason to believe, however, that they have any connection whatever with the Laboulbeniales. The individuals, which always terminate in a more slender necklike portion, consist of a basal cell attached by a black foot, above which two other cells appear to be, as a rule, obliquely related. Of these the upper appears either to abjoint or become divided into small spermatium-like bodies, which pass out through a terminal pore. Until their development has been more carefully examined, however, it has seemed best not to give names to such species as are in the possession of the writer. Of the forms illustrated, fig. 31 occurs on *Labia minor*, the others on Staphylinidae.

Amphoromorpha entomophila, nov. sp.—Plate XIX, figs. 26, 27

Pale yellowish brown, translucent, amphora-shaped, the body long elliptical or tapering below to the narrow base, abruptly contracted distally below the well defined subcylindrical terminal neck, the apex of which is slightly compressed and truncate; the foot relatively large, pointed below, somewhat spreading, black. Total length 110–130 μ, the body 70–105$\times$28–31 μ, the neck 14–17$\times$7.5–8 μ; spores about 4 μ; foot 35$\times$17 μ.

On the bristles of *Diochus conicollis* Motsch., and species of two other genera of Staphylinidae; also on a species of (?) *Labia*, Manila, Philippines.

The hosts bearing this curious plant were found among a number of miscellaneous insects which Mr. C. S. Banks of the Bureau of Science was so kind as to have collected for the writer. The individuals are solitary, and occur in small numbers projecting at an acute angle from the bristles of the legs, or of other portions of the body. Being much larger than many Laboulbeniales, they are readily seen, but no other insects have been found which

bear them, with the exception of a small bug, also from the Philippines, on two specimens of which a closely allied or perhaps identical form (fig. 29) was obtained, but not in sufficient numbers for description. It differs in its smaller size and broader blunt discharge tube.

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EXPLANATION OF PLATES XVI–XIX

The figures are reduced from camera drawings made with Zeiss dry objectives and eye-pieces and the Leitz water immersion as indicated.

Muiogone Chromopteri Thaxter

FIG. 1.—Abdomen of host showing a pustule of the fungus growing on the under surface; A4.

FIG. 2.—Two detached spores with broken stalks; D12.

FIG. 3.—Tip of a spore greatly magnified, some of the spines distally perforate; water im. 12.

Muiaria armata Thaxter

FIG. 4.—A tuft of the fungus growing on the host's leg; D4.

FIG. 5.—Two spores showing the scaly modification of the surface; D4.

Muiaria repens Thaxter

FIG. 6.—General habit of repent form on the hosts wing; A4.

FIG. 7.—Small portion of the same enlarged.

FIG. 8.—Portion of a tuft growing on the abdomen in which the spores are germinating; D4.

FIG. 9.—Surface view of single spore with basal spur and below it the ring indicating proliferation; D4.

Muiaria Lonchaeana Thaxter

FIG. 10.—Tuft of the fungus from abdomen of host showing scurfy character of the surface and rhizoidal outgrowth from base; D4.

FIG. 11.—Single spore in optical section; D4.

Muiaria gracilis Thaxter

FIG. 12.—Tuft of the fungus growing on leg of host; D2.

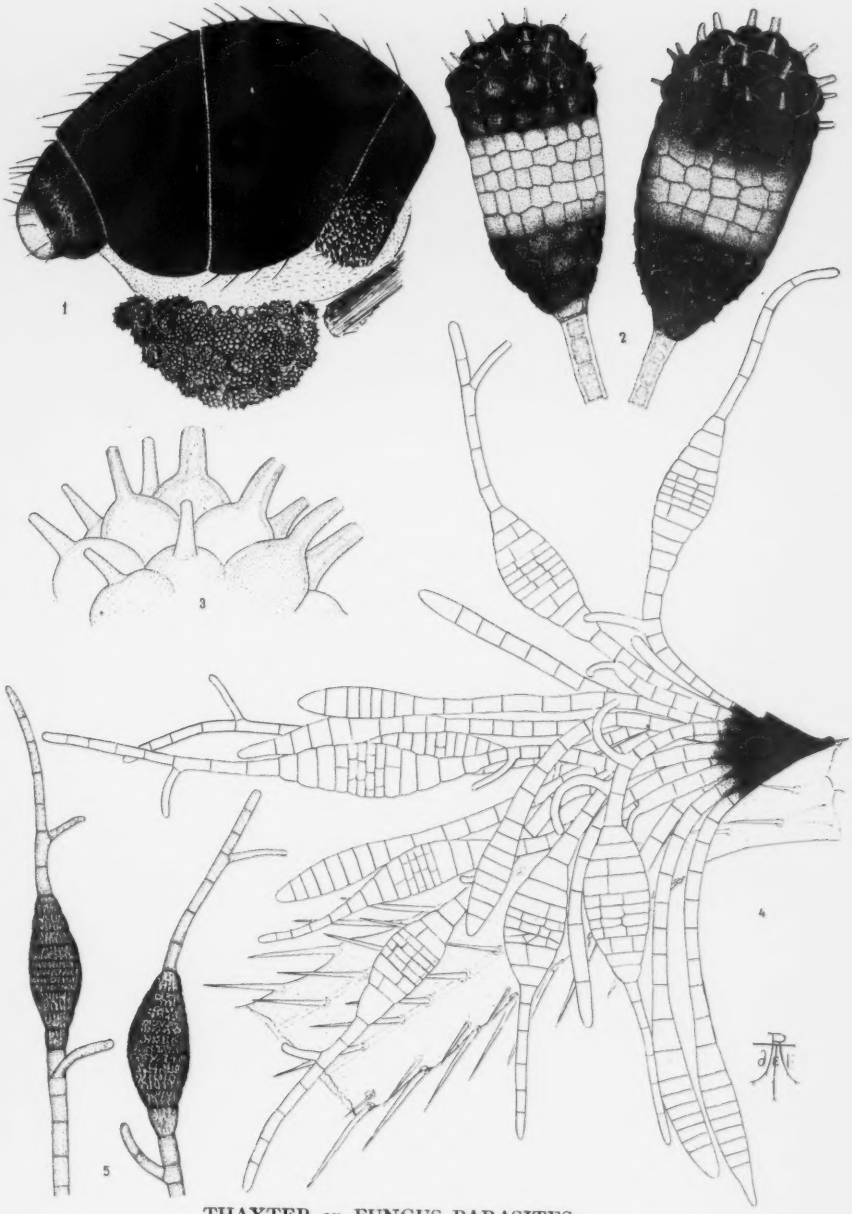
FIG. 13.—Single spore showing character of surface; D4.

Chantransiopsis Xantholini Thaxter

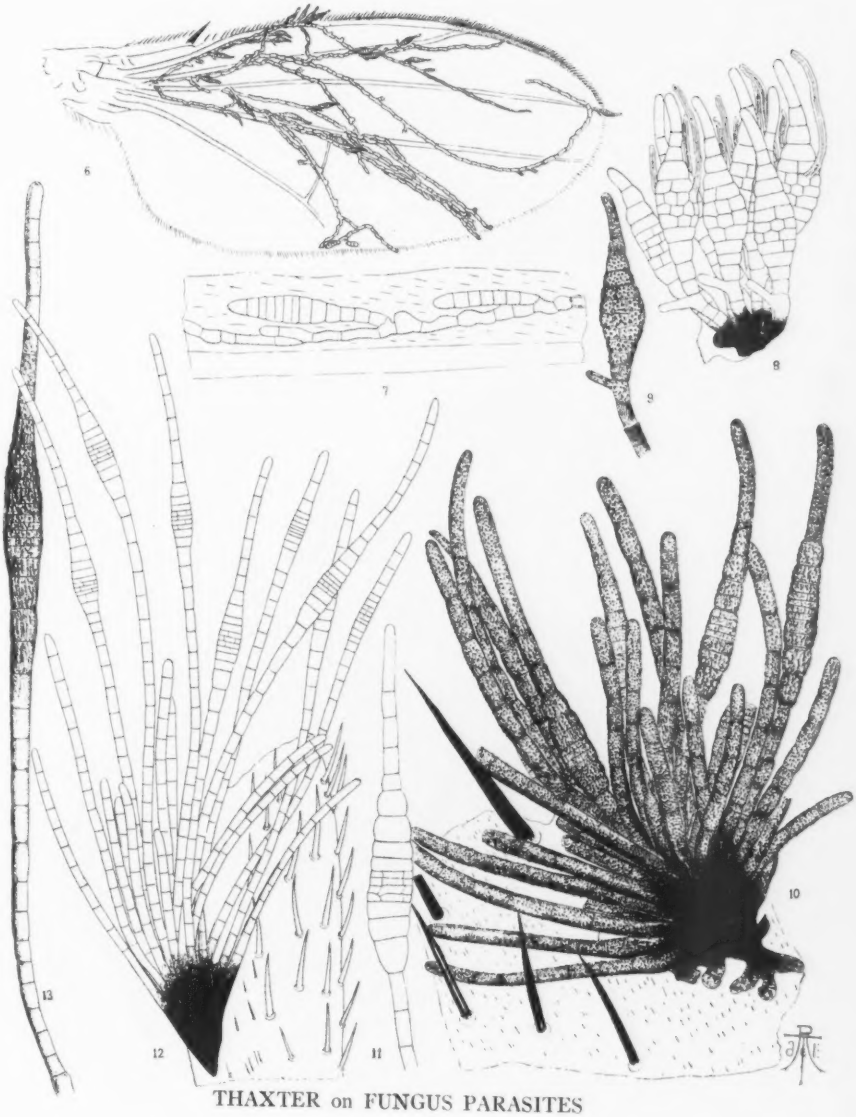
FIG. 14.—Rather large tuft with numerous spores; D4.

FIG. 15.—Tips of two sporiferous branchlets; water im. 4.

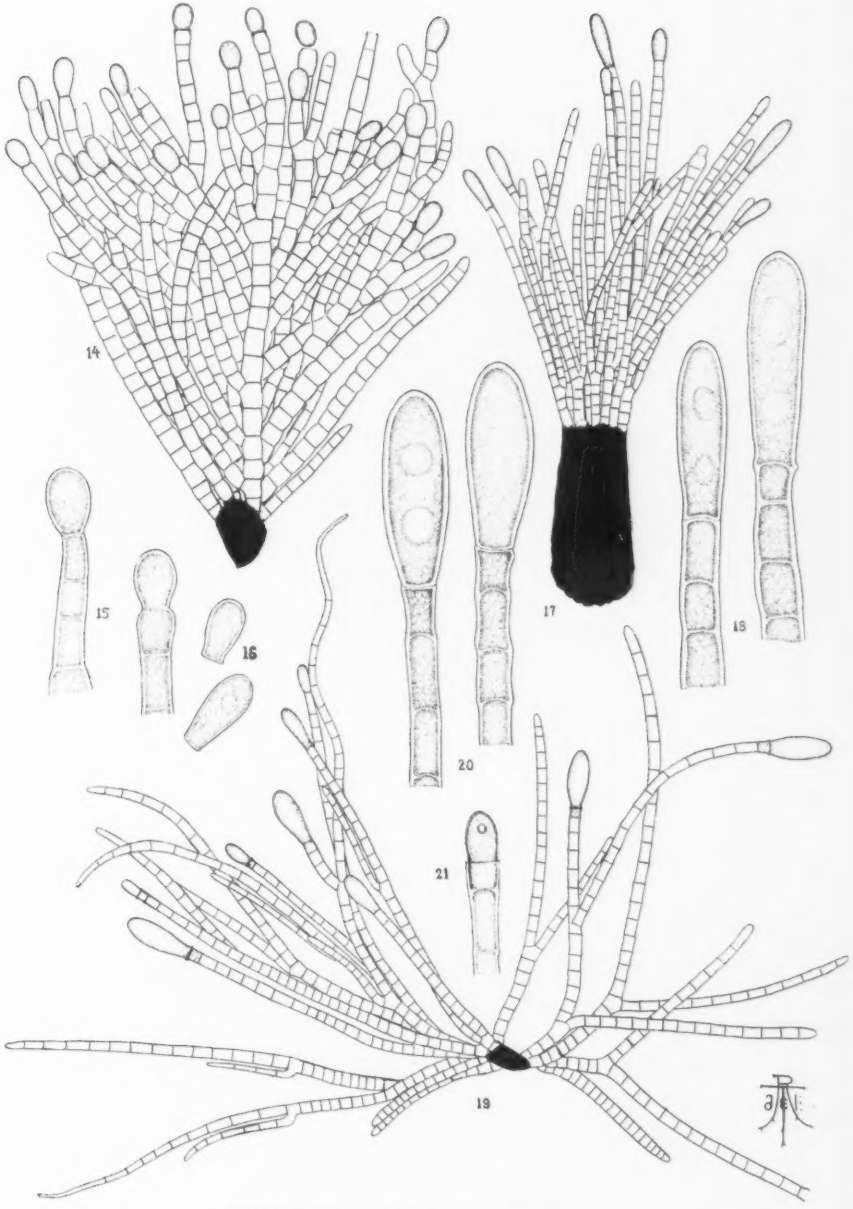
FIG. 16.—Two spores; water im. 4.



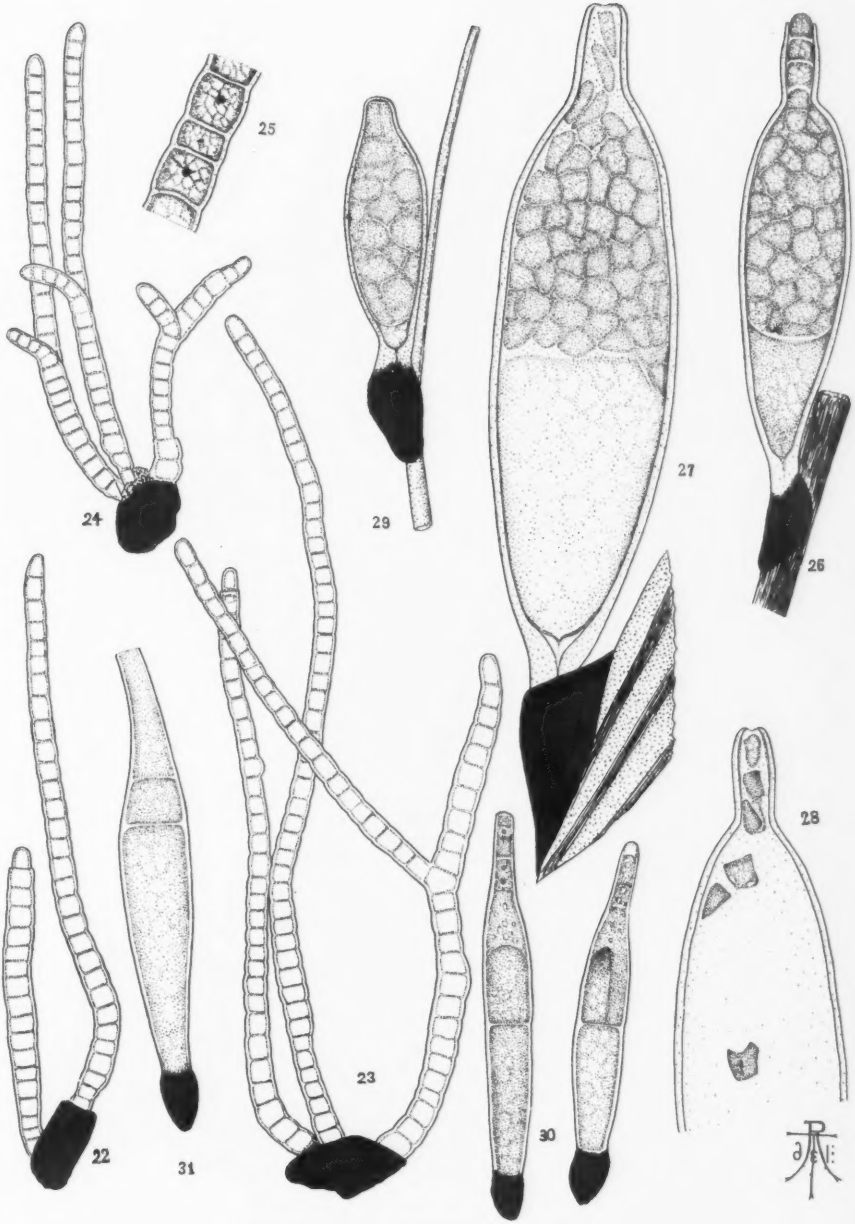
THAXTER on FUNGUS PARASITES



THAXTER on FUNGUS PARASITES



THAXTER on FUNGUS PARASITES



THAXTER on FUNGUS PARASITES

Chantransiopsis stipatus Thaxter

FIG. 17.—Portion of a much larger tuft, arising from an extensive blackened base; D2.

FIG. 18.—Tips of two sporiferous branchlets; water im. 4.

Chantransiopsis decumbens Thaxter

FIG. 19.—A whole plant showing characteristic habit; D2.

FIG. 20.—Tips of two sporiferous branchlets; water im. 4.

FIG. 21.—Tip of sporiferous branchlet showing secondary spore-formation by proliferation; water im. 4.

Hormiscium myrmecophilum Thaxter

FIGS. 22–24.—Characteristic habits of entire plants; D4.

FIG. 25.—Small portion of a filament enlarged; water im. 4.

Amphoromorpha entomophila Thaxter

FIGS. 26–27.—Two individuals *in situ;* water im. 4.

FIG. 28.—Upper portion of broken individual with isolated spores; water im. 4.

Amphoromorpha sp.

FIG. 29.—Individual from small Philippine bug; water im. 4.

FIG. 30.—A related organism from staphylinid beetles; water im. 4.

FIG. 31.—A species similar to the last from *Labia minor;* water im. 4.

THERMOTROPISM OF ROOTS

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 192

SOPHIA ECKERSON

(WITH SIX FIGURES)

I. The thermotropic curvatures of certain roots at temperatures from 10° to 40° C.

II. The changes in permeability of these roots caused by change in temperature from 10° to 40° C.

Introduction

Our knowledge of thermotropism is in a somewhat confused state. We know little about the thermotropic response of stems. A few scattered observations have been made, indicating that stem tips turn toward the source of heat at low temperatures and away from it at high temperatures. More exact investigations have been made of the thermotropic curvatures of roots, but here there seems to be no uniformity of behavior. Under the influence of unequal temperature on two sides, the roots of different species react differently. Some roots give positive curvatures at low temperatures and negative at high temperatures; others show only positive curvatures, and still others give only negative curvatures. It was with the purpose of clearing up these apparent discrepancies and the hope of finding the physical mechanism of the curvatures that the present investigation was undertaken.

Thermotropic curvatures of roots

LITERATURE

The two important papers on thermotropism of roots are WORTMANN'S (10) and KLERCKER'S (2). WORTMANN investigated four species: *Ervum lens*, *Pisum sativum*, *Zea Mays*, and *Phaseolus multiflorus*. He concluded that roots have positive thermotropism at low temperatures and negative at high tempera-

tures, that is, above 35° or 40° C. The one exception he found was *Phaseolus multiflorus*, which gave negative curvatures from 22° to 50° C., but no curvature below 22°. The secondary roots of *P. multiflorus* reacted positively at low and negatively at high temperatures. WORTMANN thought, therefore, that the primary roots must have a positive thermotropism, although he was not able to demonstrate it.

AF KLERCKER studied *Pisum sativum*, *Helianthus annuus*, *Faba vulgaris*, and *Sinapis alba*. In the first three species he observed only negative thermotropism; while *Sinapis alba* gave positive curvatures from 14° to 29° C., and no curvatures at the higher temperatures. PORODKO (7) studied the thermotropic curvatures of roots at temperatures from 40° to 70° C. He obtained negative curvatures and thought therefore that roots have only negative thermotropism.[1]

INVESTIGATION

Method.—The apparatus used is a modification of GANONG'S differential thermostat.[2] A zinc trough, 20 inches long, having a zinc box attached at each end, was heated at one end by an electric coil and cooled at the other end by a freezing mixture. This gives a fairly even gradation from 58° to 5° C. The electric coil has low, medium, and high adjustment, so that the temperature gradient in the trough can be increased or diminished as desired. Three such thermostats were in use at one time.

The seedlings chosen for this study were *Raphanus sativus* and *Pisum sativum*. The trough was filled with sterilized *Sphagnum* This was found to be the best medium, since in it the roots grow perfectly straight. Seeds were sown in the trough at definitely spaced intervals. When the roots were 1.5–2 cm. long, the thermostat was brought to the desired temperatures and the response

[1] In work described in a very recent article, HOOKER (HOOKER, HENRY D., Thermotropism in roots, Plant World **17**:135–153. 1914) obtained no reaction in roots set in 1.25 per cent agar. He concluded, therefore, that the curvatures of roots when grown in sawdust, as in the work of WORTMANN and KLERCKER, are due to hydrotropism. The methods of experimentation used are subject to criticism and the conclusions are erroneous.

[2] GANONG, W., Plant physiology, p. 207. 1908.

of the roots observed. In another series of experiments, seedlings grown at 20° C. were put directly into the heated thermostat.

Curvatures.—When seedlings of *Raphanus sativus* have been in the thermostat 2 hours, the roots show the following reactions:

Positive	No curvature	Positive	Negative
7–15° C.	16–23° C.	24–36° C.	38–51° C.

At the higher temperatures the curvature occurs very quickly. Roots grown at 20° C., when put into the thermostat at 45° C., give a positive curvature in 5 minutes. This quickly goes over into a negative curvature, so that within 20 minutes there is a strong negative curvature. The explanation of this double curvature, of course, is that as the temperature of the root rises to 38° C. there is a positive curvature; when the root temperature has reached 45° C., a negative curvature begins. It should be remembered that the side of the root toward the hot end of the thermostat is always at a slightly higher temperature than the opposite side. At the lower temperatures the roots react less rapidly, requiring 1.5–2 hours for complete reaction at 7–15° C.

TABLE I

THERMOTROPIC CURVATURES OF ROOTS

	Positive	No curvature	Positive	Negative
1. Raphanus sativus	7–15° C.	16–23° C.	24–36° C.	38–51° C.
2. Pisum sativum	8–15° C.	17–29° C.	.....	34–50° C.
——— (WORTMANN)	8.5–31° C.	.....	.....	34–50° C.
3. Sinapis alba (KLERCKER)	14–29° C.	.....	.....	None
4. Helianthus annuus (KLERCKER)	None	.....	.....	15–40° C.
5. Phaseolus multiflorus primary roots (WORTMANN)	None	8–22° C.	.....	22–50° C.
6. ———, secondary roots (WORTMANN)	10–?° C.*	.....	.....	?–40° C.*

* WORTMANN obtained positive curvatures at 10° C. and negative curvatures at 40° C., but made no investigations at the intermediate temperatures.

The roots of *Pisum sativum* are less sensitive to temperature changes than those of *Raphanus sativus*. After one hour in the thermostat all the roots at temperatures from 34° to 50° C. showed negative curvatures; and in 2.5 hours 80 per cent of those at

temperatures from 8° to 15° C. gave positive curvatures. At the temperatures from 17° to 29° C. there were no curvatures even after 9 hours.

Table I gives the thermotropic curvatures of five species, selected to show the various "types" of reaction. Where the data have been obtained by other workers, the name is given in parentheses.

In attempting to locate the mechanism of thermotropic curvatures, one must bear in mind the various possibilities, or "types" of reaction, shown in the table. The rapidity of the reaction indicates that it is not a growth phenomenon. It is known that the permeability of protoplasm increases with increase of temperature. The range of permeability change was not known, nor was it known whether there is such great variation with species as would be necessary to explain the curvatures given in table I. However, permeability changes and consequent turgor changes were considered a possible factor; accordingly the permeability of the roots at temperatures from 10° to 40° C. was determined for the five species.

II. Permeability

EFFECT OF TEMPERATURE ON PERMEABILITY

In 1902 RYSSELBERGHE (**8**) found that the permeability of the protoplasm of epidermal cells of *Tradescantia discolor* to dissolved substances (glycerine, potassium nitrate, and urea) increases with the temperature from 0° to 30° C. In 1905 LEPESCHKIN (**3**) found that the volume of liquid extruded by hairs on the leaves of *Phaseolus multiflorus* increases from 0° to 20° C., and decreases from 20° to 35° C. During the extrusion the osmotic pressure of the cell sap decreases, indicating an increased permeability to solutes as well as to water. In 1908 LEPESCHKIN (**4, 5, 6**) established the fact that pulvinal movements of leaves are due to the effect of light on the permeability of the protoplasm of the pulvinal cells. Light increases the permeability, with consequent decreased turgor pressure (decrease of volume). Darkening decreases the permeability, with consequent increase of turgor pressure (increase of volume). In 1910 TRÖNDLE (**9**) found that the leaves of *Buxus sempervirens* are more permeable to sodium chloride in light than in darkness;

also with a 32 C.-P. electric lamp as light source, he found an increase of permeability up to a certain light intensity (50 cm. from the lamp), and then a decrease at the higher intensities (35–10 cm. from the lamp).

METHOD

The method for determining permeability is essentially that of LEPESCHKIN (**6**). This method is based on the fact that the permeability of protoplasm to sucrose does not change under varying conditions, while the permeability to potassium nitrate does change. That is, with increasing permeability, higher concentrations of potassium nitrate are required to produce plasmolysis.

Weight molecular solutions were used throughout; the percentages in any series varied by 0.02 mol. The tests of permeability at the temperatures from 20° to 50° C. were carried on in a constant temperature oven, electrically controlled; those below 20° C., in an ice chest. Of course, all were in darkness. Seeds were germinated on filter paper in large Petri dishes. When the roots were about 1.5 cm. long, they were put in covered watch glasses containing the solutions and left for 20 minutes. Then they were put on a slide in a drop of the solution and observed as quickly as possible.

Repeated examination of sections of roots plasmolyzed at various temperatures showed that the degree of plasmolysis of the root hairs is an exact indication of the degree of plasmolysis of the cortical cells of the root. When the protoplasm is slightly drawn back from the tip of the root hair, the outer two rows of cortical cells are slightly plasmolyzed. When the protoplasm of the younger root hair is beginning to break up into several parts, the walls of all the cortical cells of the corresponding part of the root are slightly shrunken. In complete plasmolysis the protoplasm of the root hairs is rounded up into three or four parts, and the cortical cells are plasmolyzed. The criterion then for slight plasmolysis of the root is that condition of the root hair in which the protoplasm is slightly drawn back from the tip.

DATA

The effect of temperature on permeability is shown in the accompanying figures. The ordinates give the percentage weight-

molecular solution which produces slight plasmolysis. The increase or decrease of permeability with change of temperature is shown by the increase or decrease of these concentrations, the plasmolyzing concentration of sucrose remaining constant.

The permeability of roots of *Raphanus sativus* (fig. 1) increases from 10° to 18° C.; does not change from 18° to 24° C.; increases

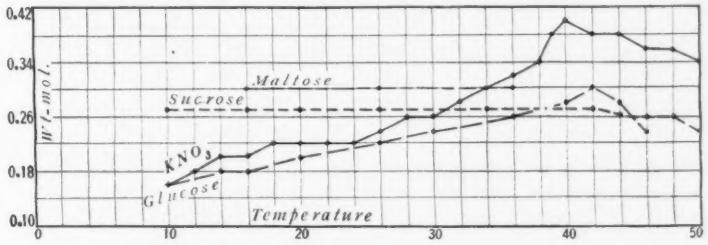


FIG. 1.—*Raphanus sativus:* curves showing the effect of temperature on the permeability of roots to potassium nitrate and glucose; ordinates indicate the percentage wt.-mol. solutions producing slight plasmolysis; dots indicate temperatures at which determinations of plasmolysis were made.

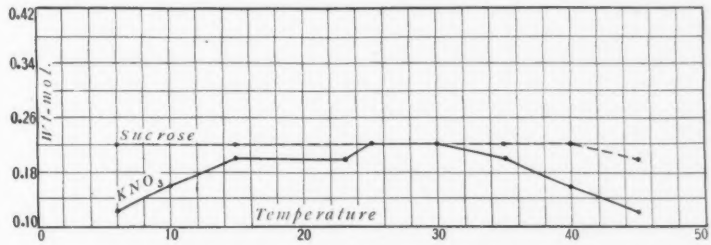


FIG. 2.—*Pisum sativum:* the potassium nitrate and sucrose curves are identical from 25° to 30° C.

from 24° to 40° C., and then decreases. The turning point in permeability to glucose is at 42° C. The drop in the sucrose curve above 42° C. suggests a decreased osmotic pressure due to exosmosis. To test this, roots were put in distilled water at 45° C.; after 20 minutes the water gave a sugar test with Fehling's solution. Thus at 42° C. there is an increased permeability, in all probability caused by coagulation of the protoplasm.

The permeability of roots of *Pisum sativum* (fig. 2) to potassium nitrate increases from 6° to 15° C.; does not change from 15° to

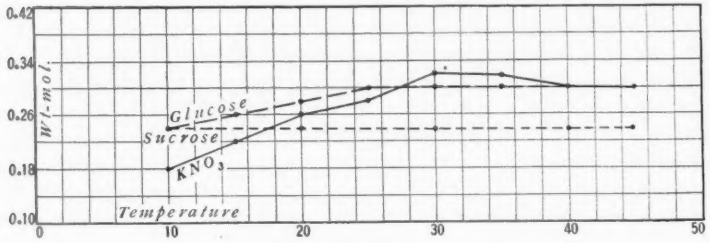


FIG. 3.—*Sinapis alba:* the potassium nitrate and glucose curves are identical from 40° to 45° C.

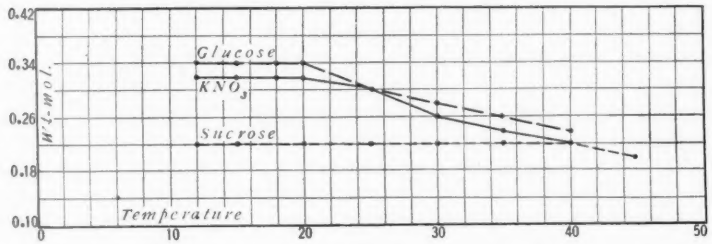


FIG. 4.—*Helianthus annuus:* the potassium nitrate and glucose curves are identical from 40° to 45° C.

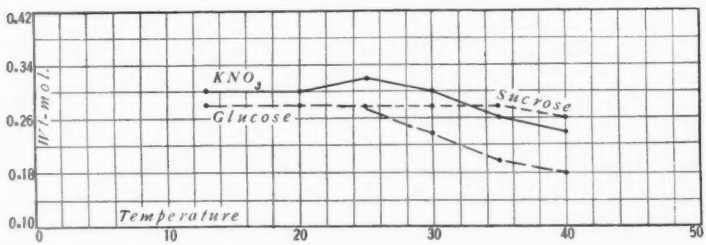


FIG. 5.—*Phaseolus multiflorus:* primary roots; the sucrose and glucose curves are identical from 15° to 25° C.

23° C.; and decreases from 30° to 40° C. The sucrose curve shows that the osmotic pressure is lower at 45° C. than at 40° C.

The permeability of *Sinapis alba* (fig. 3) increases from 10° to 25 or 30° C., then remains practically constant to 45° C.

Helianthus annuus (fig. 4) shows no increase in permeability with increase of temperature, but a decrease from 20° to 40° C.

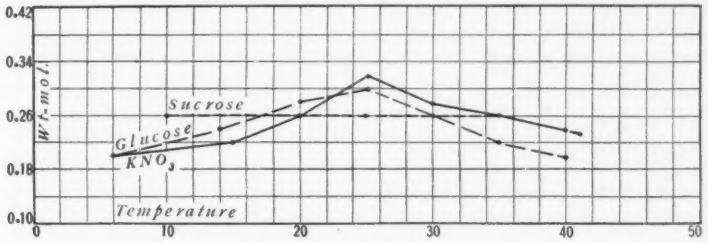


FIG. 6.—*Phaseolus multiflorus:* secondary roots; the potassium nitrate and sucrose curves are identical from 35° to 40° C.

The primary roots of *Phaseolus multiflorus* (fig. 5) show no increase in permeability from 13° to 25° C.; while in the secondary roots (fig. 6) the permeability increases from 6° to 25° C. Both have a decreasing permeability from 25° to 35° C.

COMPARISON OF THERMOTROPIC CURVATURES AND PERMEABILITY CHANGES

To show the relation between thermotropic curvatures and permeability changes, the data given in table I are given in table II

TABLE II

THERMOTROPIC CURVATURES AND PERMEABILITY VARIATIONS OF ROOTS

		+	o	+	−
1. Raphanus sativus	Curvatures	7–15° C.	16–23° C.	24–36° C.	38–51° C.
	Permeability	10–14° C.	18–24° C.	24–40° C.	40–50° C.
2. Pisum sativum	Curvatures	8–15° C.	17–29° C.	.....	34–50° C.
	Permeability	6–15° C.	15–35° C.	.....	35–45° C.
3. Sinapis alba	Curvatures (K)	14–29° C.	.....	.....	None
	Permeability	10–30° C.	30–45° C.	.....	None
4. Helianthus annuus	Curvatures (K)	None	.....	.....	15–40° C.
	Permeability	None	12–20° C.	.....	20–40° C.
5. Phaseolus multiflorus (primary roots)	Curvatures (W)	None	8–22° C.	.....	22–50° C.
	Permeability	None	13–20° C.	.....	25–40° C.
6. —— (secondary roots)	Curvatures (W)	10– ?° C.	.....	.....	?–40° C.
	Permeability	6–25° C.	.....	.....	25–40° C.

together with the temperatures at which there is increasing or decreasing permeability, for each species. In the table, + indicates positive curvatures and increasing permeability; o indicates no curvatures and no change in permeability; − indicates negative curvatures and decreasing permeability.

The data show that the permeability increase or decrease parallels almost exactly the positive or negative curvatures. In every case, at those temperatures which cause positive curvatures there is increasing permeability; where there are no curvatures, there is no change in the permeability; and at temperatures causing negative curvatures there is decreasing permeability. The slight differences in temperature at the turning point are well within the range of experimental error.

Conclusions

WORTMANN's inability to obtain positive thermotropic curvatures in the primary roots of *Phaseolus multiflorus* is explained by the fact that there is no increase in permeability. In the secondary roots, however, where he found positive curvatures, there is an increasing permeability. KLERCKER obtained no negative thermotropic curvatures in *Sinapis alba;* there is no decreasing permeability. Also, KLERCKER obtained only negative curvatures in *Helianthus annuus;* there is no increasing permeability, therefore no positive curvatures.

The permeability of the cells of the root to potassium nitrate and to glucose increases or decreases with increase of temperature according to the species, and for a given species according to the temperature.

With unequal temperature on opposite sides of a root, a curvature is produced only when the cells of the root are more permeable at one of the temperatures than at the other. Those cells which are subjected to a temperature at which they are more permeable to dissolved substances are consequently less turgid. This results in a shrinking of the tissues on that side of the root and a consequent mechanical curvature. Always the more permeable side of the root becomes concave.

Summary

1. Thermotropic curvatures of roots vary with the temperature and with the species.

2. Permeability of the cells of the root to dissolved substances varies with the same factors.

3. In every case the greater permeability is in the concave side of the root; where the thermotropic reaction of the root changes, the permeability also changes.

4. The parallelism between the permeability and thermotropic reaction is exact; turgor change produced by permeability change offers a mechanical explanation of the curvature.

5. Heat does not act as a stimulus, but by affecting permeability as a direct factor producing curvature; hence, thermotropism is not a tropism, but is a turgor movement.

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OOGENESIS IN HORMOSIRA

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 193

M. R. GETMAN

(WITH PLATE XX AND SEVEN FIGURES)

The genus *Hormosira* is placed by OLTMANNS (7) under the Fucaceae and classified with *Notheia* in the family Anomalae, characterized by him as a group of small and perhaps reduced forms. The genus is fully described and illustrated by HARVEY (giving DECAISNE as authority) in his *Phycologia Australica* (3). The larger plant he names *H. Banksii* var. *Labillardieri* or *Billardieri* (fig. 1), and the smaller, *H. Banksii* var. *Sieberi* or *obconica* (figs. 2 and 3). HOOKER (quoting ENDLICHER) in the *Handbook of New Zealand flora* (4) describes the same forms, naming the first *H. Billardieri* var. *Labillardieri*, and the second, var. *Sieberi*.

The material used in this study was collected by Dr. C. J. CHAMBERLAIN at Avoca, near Sydney, on the eastern coast of Australia. It occurs in the tide pools and on rocks where it is constantly exposed to the dashing of salt spray.

The plant varies in color from an orange-brown to an olive-green. It has no differentiation into parts, but is merely a chain or "necklace" of swollen vesicles or bladders which bear the conceptacles. HOOKER refers to the plant as a series of internodes (the inflated portions) alternating with smaller narrower parts (the nodes). The development, according to GRUBER (2), is from four apical cells. Branching commonly occurs at the internodes, but it may take place at the nodes. It is usually dichotomous, but cases of trichotomy are common, and even polychotomy has been observed. Each internode, excepting the one at the base, contains a central cavity. In fresh material threads may be seen extending from the base to the top of this cavity. The internode consists of an external mucilaginous layer varying in thickness depending upon the age of the plant and the position of the internode. This epidermis or outer layer BOWER (1) prefers to call

limiting tissue. Underneath lies the cortex, and beneath this a thick mass of anastomosing filaments, termed irregular tissue by

FIG. 1.—*Hormosira Banksii* var. *Labillardieri*

FIG. 2.—*Hormosira Banksii* var. *Sieberi:* mature oogonial plant.

MOLLET (**6**). These cells are very gelatinous and are limited below by a layer of parallel cells (fig. 4).

There is no cavity in the node. An epidermis and cortical layer are both present, and its center is made up of parallel cells, which divide into two strands as they pass into the internode below. At the distal end of the node there seems to be a decrease in parallel cells as they merge into the anastomosing filaments (fig. 5).

The plant is dioecious. The antheridial plants are readily recognizable on account of the bright orange color. The conceptacles are flask-shaped, and are sunken in the outer tissues of the internode. From the few observations made of the conceptacle, the development seems to tally with BOWER'S account (**1**) of its development in the Fucaceae, where the basal cell (*b*) and adjoining cells contribute to the growth of the conceptacle. In the figure, BOWER'S "initial cell" shows a nucleate stage (fig. 6). A later stage of the conceptacle furnishes characteristic paraphyses (fig. 7), a few of which may persist in the mature oogonial conceptacle, but whose place is taken almost entirely by hairs of a different nature.

It will be recalled that the several genera of the Fucaceae, in their oogenesis, present an interesting illustration of recapitulation. Of the members of this family which have been investigated, all except *Sargassum* show three mitoses in the oogonium, resulting in the formation of eight nuclei. In the genus *Fucus*, all the nuclei are centers for the formation of the eggs. In another genus,

FIG. 3.—*Hormosira Banksii* var. *Sieberi:* young plants

Ascophyllum, OLTMANNS found four functional eggs. In *Pelvetia* he found that only two eggs mature and that the other six nuclei abort. In *Himanthalia*, OLTMANNS (**8**) found only one egg, and YAMANOUCHI has observed the same condition in *Cystosira*. In both cases the other seven nuclei degenerate. In *Sargassum filipendulum*, Miss SIMONS (**9**) finds no mitosis after the formation of the oocyst, and therefore the $2x$ number of chromosomes should

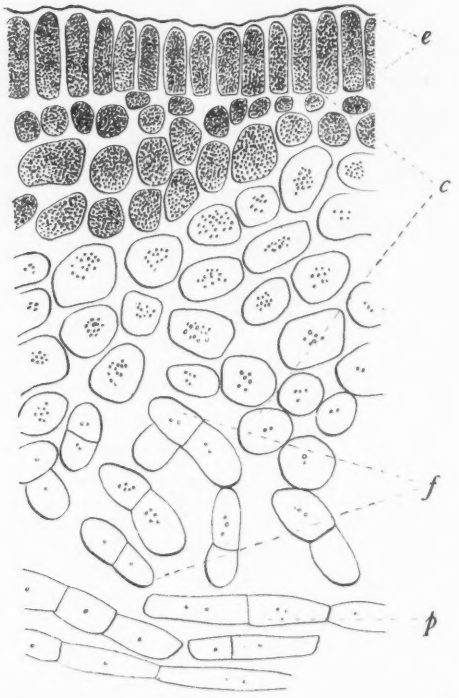

FIG. 4.—Portion of an internode: *e*, limiting tissue or epidermis; *c*, cortex; , anastomosing filaments; *p*, parallel tissue; ×250.

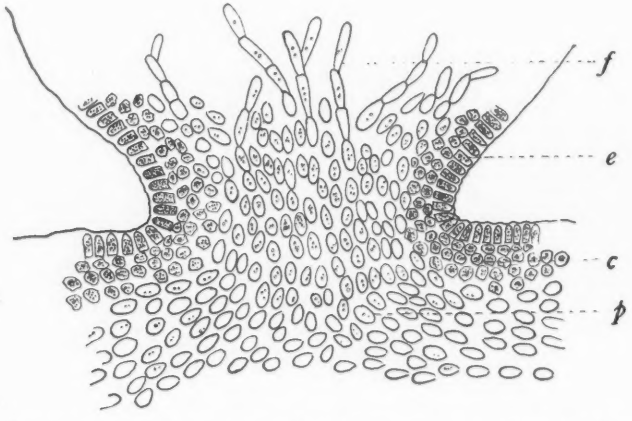

FIG. 5.—Structure of a node: *e*, epidermis; *c*, cortex; *f*, anastomosing filaments; *p*, parallel tissue; ×85.

be present in the egg. Since there has been no reduction division, the three mitoses characteristic of oogenesis in *Fucus* have been suppressed in *Sargassum*. However, out of the large number of conceptacles examined in this form, one oogonium was found which contained two eggs and two oogonia that contained eight; this was regarded as a rare reversion to the *Fucus* type. The above instances in oogenesis form a series beginning with the eight eggs of *Fucus* and ending with the parthenogenetically developed egg of *Sargassum*. Oogenesis in *Fucus* is regarded as the primitive type and the others as reductions from it.

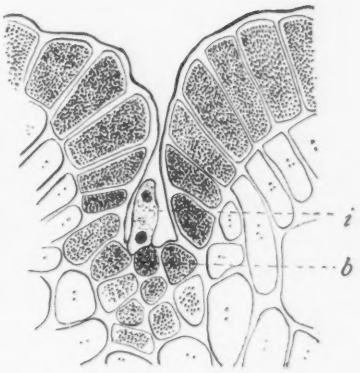

FIG. 6.—Conceptacle: *a*, BOWER'S "initial"; *b*, "basal" cell; ×480.

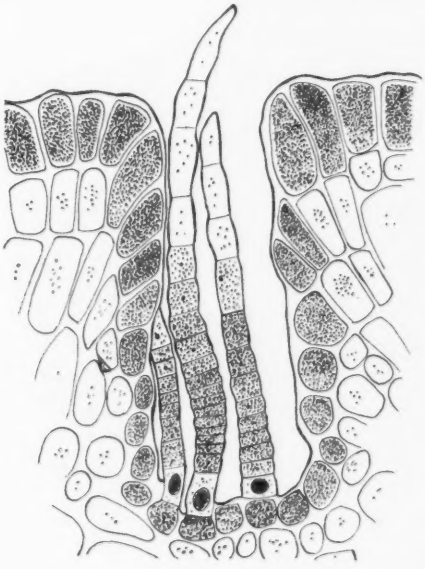

FIG. 7.—Conceptacle: first formed paraphyses; ×410.

OLTMANNS, KUTZING, and GRUBER have all mentioned the ultimate formation of four eggs in *Hormosira*, but no investigation has been made of the conditions of oogenesis.

The material was fixed in Flemming's weaker solution with the osmic acid a little weaker than the formula requires. As in OLTMANNS' account of *Ascophyllum*, simultaneous free nuclear division takes place, resulting in 2-nucleate, 4-nucleate, and 8-nucleate stages (figs.

8–10). Thus far, the conditions seem the same as for *Ascophyllum*. After this the account differs, for the coming in of walls was observed in many cases. For instance, a rather unusual case is the occurrence of seven nuclei, and the division into three parts by two horizontal walls (fig. 11). The coming in of a vertical wall after the formation of a single horizontal one is also found (fig. 12). The most usual situation seems to be a blocking out by walls of the nuclei and the plastids (fig. 13). Here six such characteristic groups can be seen and also a seventh nucleus. Rarely (fig. 14) four eggs are formed and eight nuclei are present. This may be a situation immediately preceding that presented in fig. 15, or the walls shown in fig. 13 may have disintegrated, leaving only the primary walls. No spindles were seen to account for the formation of the walls. They may have been formed by cleavage as does happen among certain of the algae and fungi.

While the details of oogenesis remain to be investigated in several genera of the Fucaceae, it seems certain that the 8-nucleate condition followed by eight functioning eggs is primitive, and that most of the genera which form less than eight eggs pass through this stage.

This study of *Hormosira* shows that not only are eight nuclei formed, but eight eggs begin to develop, so that the final 4-nucleate condition is reached by the breaking down of four immature eggs rather than of four free nuclei. Such a condition is safely interpreted as less removed from the *Fucus* condition than forms in which the 4-nucleate stage is reached by the breaking down of free nuclei.

I am very much indebted to Dr. C. J. CHAMBERLAIN under whose direction the work was done, and to Dr. W. J. G. LAND for the photographs in the text.

UNIVERSITY OF CHICAGO

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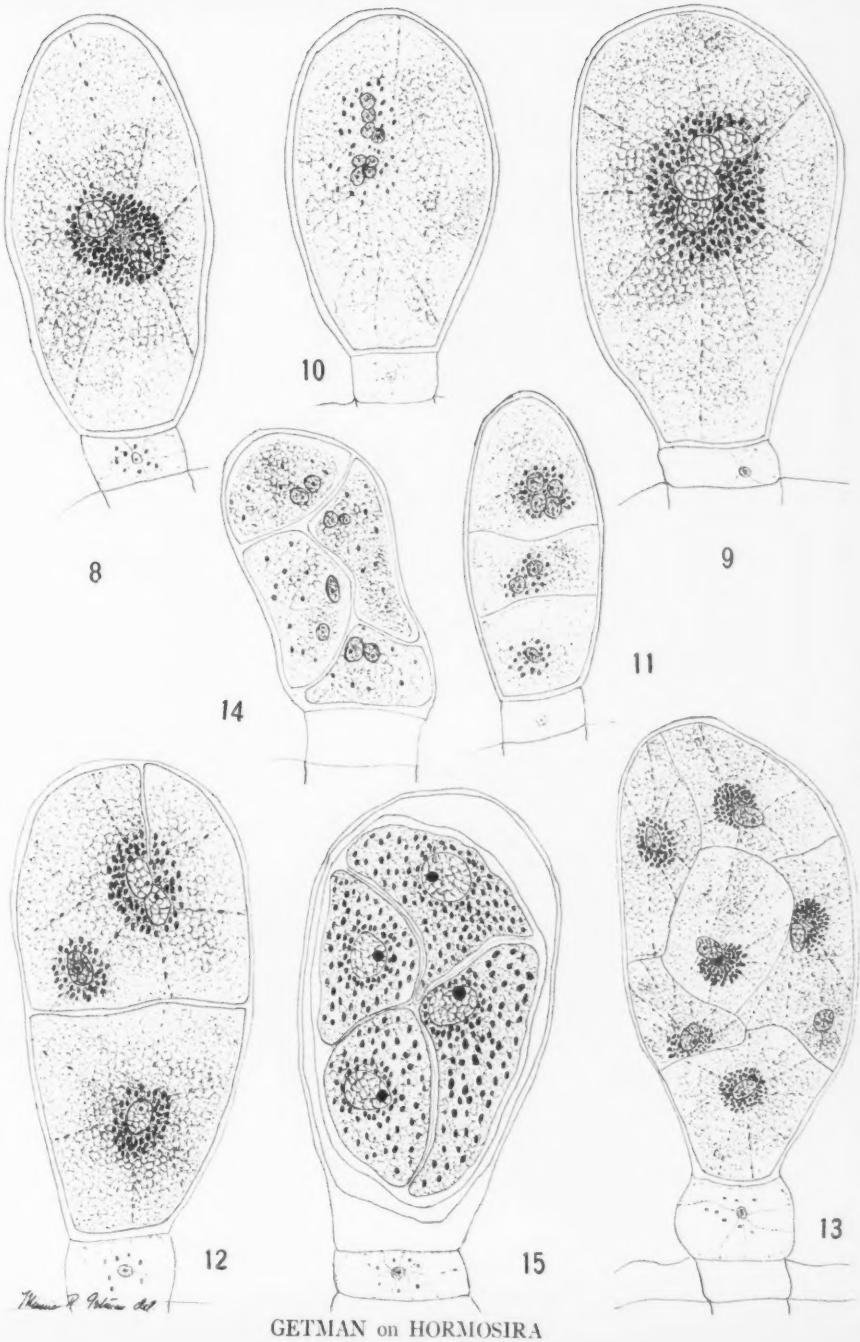

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EXPLANATION OF PLATE XX

FIGS. 1–7 are text cuts. All figs. of the plate ×480.

FIGS. 8–10.—Free-nucleate condition.

FIGS. 11, 12.—Development of walls.

FIG. 13.—Blocking out of six eggs; a seventh nucleus showing.

FIG. 14.—Four eggs and eight nuclei; the four other eggs have degenerated.

FIG. 15.—Four mature eggs.

THE MEASUREMENT OF ANTAGONISM

W. J. V. Osterhout

(with three figures)

Attention has been called to the need of a quantitative criterion of antagonism, and it has been shown that such a criterion is easily secured by mixing equally toxic solutions. In this paper[1] mixtures of more than two components were not considered. In order to clear up more fully the confusion which still exists in regard to the measurement of antagonism, it seems advisable to point out the special advantages of this method for mixtures containing three or more components.

The chief advantages lie in the fact that when equally toxic solutions are mixed, the additive effect remains unaltered, no matter how many components are used.[2] (By the additive effect is meant the effect produced when each salt acts independently of every other, when its toxicity is neither augmented nor diminished by the presence of other salts.) If antagonism exists, there will be better growth in the mixtures than in the pure solutions. The increase of growth over what would be expected if the effect were purely additive is the best measure of antagonism. It is best expressed as percentage of the additive effect.[1]

The determination of the additive effect is of first importance for quantitative results. The best method is that which permits us to make this determination most readily and exactly. As has been said, the method of mixing equally toxic solutions makes this determination simple and accurate, no matter how many components are used. Other methods permit this determination for binary solutions, but they involve much more labor, and as the number of components increases, the difficulty of determining the

[1] Osterhout, W. J. V., Quantitative criteria of antagonism. Bot. Gaz. **58**:178. 1914.

[2] When the toxic effect depends on ions, it may increase somewhat as the result of mixing the solutions because the ionization is increased. But this effect is usually small and it may be calculated without difficulty.

additive effect increases very rapidly. These methods usually consist in mixing unequally toxic solutions or in keeping the concentration of some salt or salts constant while varying that of the others.

The method of mixing equally toxic solutions also has a great advantage when the results are to be expressed graphically. As an illustration of this we may take mixtures of NaCl+KCl+$CaCl_2$. In the case of wheat it was found that the roots grew equally well in solutions of NaCl 0.12 M, KCl 0.13 M, and $CaCl_2$ 0.164 M. Mixtures of these solutions were prepared and the growth of the roots in these mixtures was measured after a period of 30 days. In order to show the results graphically, the composition of the solutions may be conveniently expressed by means of a triangular diagram as drawn in fig. 1.[3]

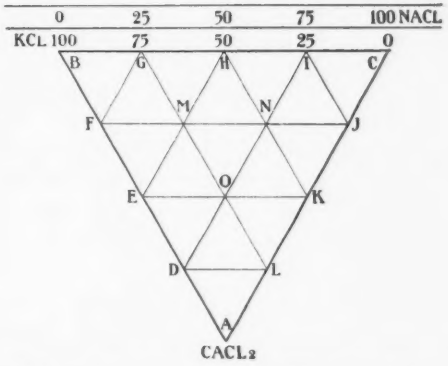

FIG. 1.—Diagram representing the composition of various mixtures of KCl+NaCl+$CaCl_2$: this serves as the base of the solid model shown in fig. 2.

The diagram consists of an equilateral triangle, the apices of which represent equally toxic pure solutions. Thus the point *A* represents pure $CaCl_2$ (0.164 M), *B* represents pure KCl (0.13 M), and *C* represents pure NaCl (0.12 M). All points on the sides of the triangle represent mixtures of two solutions only, the composition depending on the position of the point. Thus the point *H* represents a solution made by mixing the equally toxic solutions NaCl 0.12 M and KCl 0.13 M in such proportions that in the mixture 50 per cent of the dissolved molecules are NaCl and 50 per cent are

[3] These diagrams are employed in physical chemistry and have been used by SCHREINER and SKINNER in plant physiology (BOT. GAZ. **50**:1. 1910). Finely ruled diagrams may be purchased from the Cornell Cooperative Society.

KCl. In the same way *G* represents a solution in which the molecular proportions are NaCl 25 per cent+KCl 75 per cent; *I* represents NaCl 75 per cent+KCl 25 per cent; *E* represents KCl 50 per cent+$CaCl_2$ 50 per cent; *K* represents NaCl 50 per cent+$CaCl_2$ 50 per cent.

All points in the interior of the triangle represent mixtures of the three equally toxic solutions NaCl 0.12 M, KCl 0.13 M, and $CaCl_2$ 0.164 M. Along the line *FJ* are represented mixtures in which the dissolved molecules are 25 per cent $CaCl_2$; the line *EK* represents mixtures in which the dissolved molecules are 50 per cent $CaCl_2$; the line *DL* mixtures in which the dissolved molecules are 75 per cent $CaCl_2$. In the same way *FG* means 75 per cent KCl; *EH*, 50 per cent KCl; *DI*, 25 per cent KCl; *GL*, 25 per cent NaCl; *HK*, 50 per cent NaCl; and *IJ*, 75 per cent NaCl.

The point *M* is on the line *FJ*, meaning 25 per cent $CaCl_2$; it is also on the line *EH*, meaning 50 per cent KCl; and likewise on the line *GL*, meaning 25 per cent NaCl. It therefore represents a mixture of the three equally toxic solutions, NaCl 0.12 M, KCl 0.13 M, and $CaCl_2$ 0.164 M, in which the dissolved molecules are 25 per cent $CaCl_2$+50 per cent KCl+25 per cent NaCl. In the same way the point *O* represents a mixture in which the dissolved molecules are 50 per cent $CaCl_2$+25 per cent KCl+25 per cent NaCl.

It is obvious that the composition of any solution can be represented by selecting a suitable point on the diagram. At any such point an ordinate may be erected expressing the growth of the plant in that solution. When this has been done for a sufficient number of points, a solid model may be constructed which gives a complete description of the growth of the plant in all the solutions. Such a model is shown in fig. 2. The ordinates represent the aggregate length of roots per plant of wheat at the end of 30 days. The ordinates in the pure solutions are all equal (55 mm.), showing that the solutions are equally toxic. The ordinates were in part determined directly by experiment and in part calculated from data obtained by growing plants in solutions of approximately the same composition as those represented.[4]

[4] The data from which this model was constructed will appear in a subsequent publication.

From such a model the antagonism in any solution may be determined at once by measuring with calipers the height of the ordinate at the required point, subtracting 55 which is the amount of growth in the pure solutions, and in this case (since all the pure solutions are equally toxic) the amount of growth which would occur if the toxic actions of the salts were additive (that is, if each salt exerted its own toxic effect independently of the other salts); the result should then be divided by 55.[5]

In this case the additive effect is represented by a plane surface parallel to the plane which forms the base of the model. The height of this plane is indicated by the shading in the figure.

Other methods (as mixing unequally toxic solutions or keeping the concentration of one salt constant while varying that of the others) will give for the additive effect a curved surface very difficult to determine and not easily represented or measured on the model.

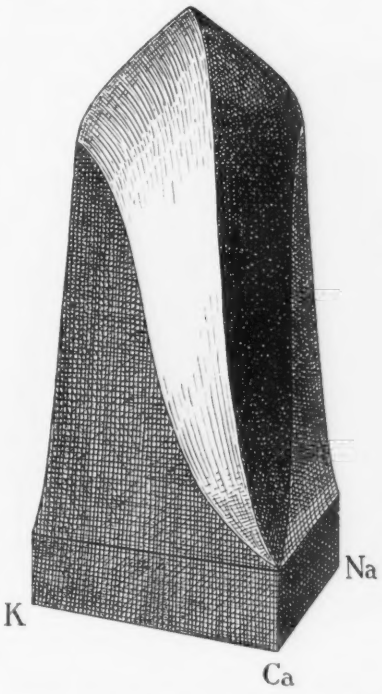

FIG. 2.—Solid model showing the forms of the antagonism curves in all possible mixtures of NaCl 0.12 M, KCl 0.13 M, and $CaCl_2$ 0.164 M.

With solutions of more than three components the results cannot be expressed in a solid model; but a graphical expression may easily be obtained in the following way. Let us suppose that equally toxic solutions of *A*, *B*, *C*, and *D* are to be mixed. A mixture of the first three may be made and called solution 1 (different mixtures may be called solution 2, etc.). To solution 1 various amounts of *D*

[5] For a fuller discussion see BOT. GAZ. **58**:178. 1914.

may be added and the results plotted as shown in fig. 3, in which the additive effect is expressed by the dotted line and the growth in the mixtures by the unbroken line. Antagonism at any point may be easily expressed. For example, the antagonism at the point M is $\frac{MO-MN}{MN}$.

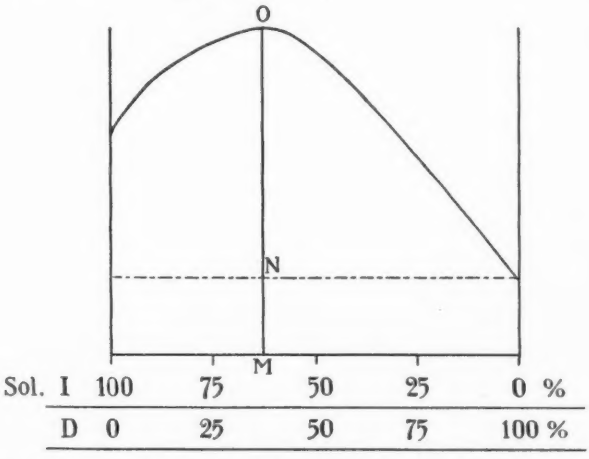

FIG. 3.—Method of expressing antagonism in mixtures containing more than three components: three of the components (A, B, and C) are combined into solution 1 and various amounts of the fourth component (D) are added; the ordinates represent growth; the abscissas represent the composition of the mixtures; thus at the point M the mixture contains 62.5 cc. of solution 1 to each 37.5 cc. of solution D, the antagonism at M is $\frac{ON}{MN}$.

By the method of mixing unequally toxic, pure solutions or by the method of keeping the concentration of one salt constant while varying that of the others, the dotted line would become a curved one.

Summary

The measurement of antagonism in solutions containing more than two components presents no difficulty as long as we pursue the method of mixing equally toxic pure solutions.

Methods are suggested for the graphical expression of antagonism in mixtures of three or more components.

HARVARD UNIVERSITY

FIELD NOTES ON THE CLIMBING BAMBOOS OF PORTO RICO

AGNES CHASE

(WITH PLATE XXI)

In two months spent in the study and collection of grasses in Porto Rico in the fall of 1913, the writer became acquainted with the habits and field aspect of the beautiful and interesting climbing bamboos of the island. The botanical descriptions published, having been drawn from herbarium material, fail to give much idea of the appearance of the living plants.

The climbing bamboos, with the tree ferns and mountain palms, are characteristic of the mountain regions from 2000 feet altitude upward to the summits. At present four species are known: *Arthrostylidium multispicatum* Pilg., *A. sarmentosum* Pilg., *A. angustifolium* Nash, and *Chusquea abietifolia* Griseb. Sterile plants of the last were collected by Dr. F. L. STEVENS and Mr. W. E. HESS on Monte Alegrillo in November 1913, but this species was not found by the writer. The three species of *Arthrostylidium* have much the same habit, climbing high, repeatedly branching, and in their greatest development swinging down in great curtains from the trees overhanging trails or streamlets. They love the glints of sunlight along the trails or water courses and are very rarely found in deep shade On mature culms two sorts of branches are produced, short leafy ones in whorls at the nodes, and elongated ones which bear whorls of short leafy branches and branch again, the process being repeated until at times a slope for several yards is bound together in a tangled mass.

Arthrostylidium angustifolium, a species very closely related to the Cuban *A. capillifolium* Griseb., I found only once near a cataract at some 3000 feet or more in Indiera Fria. This has linear blades, 2 to 4 mm. wide and as much as 30 cm. long, crowded on short sterile branchlets which are arranged in dense whorls at the distant nodes of the slender culms. These culms hang straight 20 or 30 feet from trees 40 or 50 feet high, or festoon themselves over

lower growth, the dense masses of foliage like great pompons strung along the stems at distant intervals. From these whorls occasionally spring slender, divaricate, elongated branches bearing leafy tufts like those of the main culms, but less dense and with shorter blades, the ultimate branches almost capillary and bearing but a single leaf at a node.

Arthrostylidium multispicatum occurs on most of the wet higher mountains. The slender naked growing ends of the culms and branches are beset with very short, sharp-pointed retrorse prickles. These ends, from 5 to 12 feet or more long, swing in the breeze like whip lashes until they strike a place to take hold. Only after attaching themselves to some support do the leaves and branches develop from the clusters of short, sharp, radiating, scale-covered branch buds. The prickles later fall off, the old culms being smooth. These long grappling branches are freely produced, resulting in an inextricably tangled mass that draws blood at every foot of one's progress through it. The short leafy branches are rather less densely whorled than in either of the other species, there being from few to about 20 at a node. The lanceolate, not crowded, blades are 6–8 cm. long and 10–12 mm. wide, or, on vigorous shoots in rich spots, 10 cm. long and 2.5 cm. wide.

The most beautiful and interesting of the climbing bamboos is *Arthrostylidium sarmentosum*. This I found on nearly every wet high mountain, having collections from ten stations. It had been collected before in but three stations and was unknown in flower, the original description having been drawn from sterile specimens. Among mountain palms on the forested north slope of El Yunque (ascending from Rio Grande), at about 3000 feet altitude, it was found in abundant bloom December 2, 1913 (CHASE no. 6730). This is the only time it has been known to flower. The conditions here, so far as could be seen, were in no way different from those under which it grew elsewhere and failed to bloom. Fifty herbarium specimens were prepared and several have since been distributed to herbaria in this country and in Europe. The inflorescence consists of short-exserted, terminal and axillary, strongly zigzag racemes of 2–5 spikelets, the rachis joints flat on one side, minutely ciliate on the edges, a strong pulvillus at the base of each joint forcing it to bend back at right angles to the joint below.

CHASE on ARTHROSTYLIDIUM

Spikelets sessile, 12–20 mm. long, slender, the slender, clavate rachilla joints zigzag, 3–5 mm. long; glumes 3 or 4, approximate (the lower internodes of the rachilla about 0.1 mm.), the strong midnerves hispidulous toward the summit, the lowermost glume acuminate or setaceous, 2.5–3 mm. long, the uppermost acute, 4–4.5 mm. long, about equaling the rachilla joint; florets 2 or 3, nearly terete, 6–8 mm. long, distant, one-third to one-quarter longer than their rachilla joints; lemma lanceolate, acuminate, pubescent, with three strong nerves and one or two pairs of faint intermediate nerves; palea membranaceous, slightly shorter than its lemma, broad, obtuse, deeply folded between the ciliate keels; stamens 3; stigmas 2, plumose.

From my observations, I think this species forms an exception in the bamboos in that the culms are not perennial but herbaceous, dying down each year. When first seen along the Rio Maricao, the middle of October, there were numerous young culms, from a foot or two to six or eight feet long, crawling on the ground or beginning to climb. Hanging in the trees overhead were quantities of frayed dead stems falling to pieces when touched. By the last of December this species was high in the trees and hanging down like the other two species. There are no strong culms as in other bamboos or in *Lasiacis;* the largest found is but 3 mm. in diameter. The culms are not more woody in texture than are those of some of our species of *Panicum* or *Andropogon*. Since there is neither winter nor dry season, there seems to be no reason why the plants should die down, but apparently they do die down like ordinary grasses that are perennial by underground parts only. It is a most airy, graceful, delicately beautiful species, the long, slender, vinelike culms with their clusters of pale green foliage festooning the trees or hanging free from the long limbs above a trail or rivulet and suggesting a lacy veil. The foliage becomes glaucous in drying, but in the growing plants is a light but not grayish green.

Bureau of Plant Industry
Washington, D.C.

EXPLANATION OF PLATE XXI

Arthrostylidium sarmentosum Pilg.: *a*, portion of culm with inflorescence, $\times\frac{1}{2}$; *b*, spikelet with portion of rachilla, $\times 3$.

CURRENT LITERATURE

NOTES FOR STUDENTS

The wilting coefficient.—The importance in ecological work of some method of determining what portion of the soil moisture is available for the growth of plants caused ecologists to welcome the "wilting coefficient" of BRIGGS and SHANTZ[1] as an important constant for the investigation of plant associations. The general conclusion that for any given soil the wilting coefficient is largely independent of the kind of plant or of the external conditions under which the plant grew and wilted was directly at variance with the ideas of plant physiologists and was soon questioned. Unfortunately, in the extensive and careful experiments of BRIGGS and SHANTZ there was no exact quantitative description of the atmospheric factors under which the experiments were carried out. Limiting these factors rather definitely, CALDWELL[2] found that only when wilting was slowly brought about under rather moist conditions was the wilting coefficient, or "the ratio of soil moisture content at permanent wilting," the same as that determined by BRIGGS and SHANTZ. Similar plants placed under the high transpiration condition of the desert atmosphere at Tucson wilted with a soil moisture content 30–40 per cent in excess of the wilting coefficient for the humid aerial conditions, the difference being greatest in soils with a low saturation capacity, although under a given set of atmospheric conditions the wilting coefficient was approximately a constant for each of the soils used. In order that the wilting coefficient may be determined solely by soil conditions, therefore, it is only necessary that the evaporating power of the air shall not exceed a certain limit, but where this limit lies, beyond which this coefficient is decidedly greater than that determined by BRIGGS and SHANTZ, was not determined.

BLACKMAN[3] has recently reviewed the situation, including CRUMP'S[4] new method of expressing the soil moisture (coefficient of humidity) and has aptly pointed out what appears to be some of the important related ecological problems of the water relations of plants urgently requiring investigation. They are (1) the confirmation of the results of BRIGGS and MCLANE (on the moisture equivalent of soils), and of BRIGGS and SHANTZ; and (2) how far the formula

[1] See BOT. GAZ. **53**:20–37, 229–235. 1912.

[2] CALDWELL, J. S., The relation of environmental conditions to the phenomenon of permanent wilting in plants. Physiol. Res. **1**:1–56. 1913.

[3] BLACKMAN, V. H., The wilting coefficient of the soil. Jour. Ecol. **2**:43–50. 1914.

[4] See review in BOT. GAZ. **57**:85. 1914.

devised by BRIGGS and SHANTZ to express the wilting coefficient in terms of soil composition is capable of simple modification for higher rates of transpiration. As there seems to be no reason at all to doubt the experimental accuracy of the work of BRIGGS and SHANTZ, especially when their extensive character is taken into consideration, the second of these problems would seem to offer a favorable field for further experimentation, with a strong probability of results that would be useful in many phases of ecological study. Indeed, the most recent paper upon the subject by SHIVE and LIVINGSTON[5] makes an unsuccessful attempt at a determination of the limits within which the formula of BRIGGS and SHANTZ does apply. It confirms the results of CALDWELL, further emphasis being given to the fact that for the soils of high water-holding powers the wilting coefficient, or the "soil moisture residue at permanent wilting" as SHIVE and LIVINGSTON prefer to call it, even with high evaporating power of the air, is but little above, in fact, in some instances, is slightly below that obtained by the direct methods of BRIGGS and SHANTZ. This paper also contains an attempt to express by an algebraic equation the relation of the wilting coefficient to the evaporation intensity under which wilting was brought about, but the results are so diverse that only a rather wide approximation is obtained. The general conclusion seems to be that the formula of BRIGGS and SHANTZ holds within certain limits, as yet undetermined, but doubtless within atmospheric conditions of comparatively low evaporation intensity.—GEO. D. FULLER.

Ecology of fresh-water algae.—COMERE[6] has published a general account of the ecology of the fresh-water algae. The paper itself is so nearly a summary of the results of investigations by the author and other European limnologists, that it is difficult to condense the matter further. The paper is divided in three parts, the first of which considers the classification and nomenclature of aquatic formations, the separation of these formations into characteristic regions, and the arrangement and terminology of the "florules" corresponding to these regions. This part is especially useful because of its concise definitions and citations of synonyms. Algal habitats are primarily divided into aquatic and subaerial. The former are further separated into permanent and transient groups. The algal formations are first divided into those of large lakes, small lakes, and streams. In these there may be further recognized the littoral, planctonic, and bottom regions, each with its corresponding florule. The subdivisions are too numerous to mention here, but this will suffice to show that

[5] SHIVE, J. W., and LIVINGSTON, B. E., The relation of atmospheric evaporating power to soil moisture content at permanent wilting in plants. Plant World **7**:81–121. 1914.

[6] COMERE, JOSEPH, De l'action du milieu considérée dans ses rapports avec la distribution générale des Algues d'eau douce. Mém. 25, Bull. Soc. Bot. France **16**: 1–96. 1913.

the basis of classification is essentially static, and ignores the genetic relationships of both the habitats and the formations. Consequently, proximity in the resulting scheme of classification does not necessarily imply near relationship, nor wide separation a lack of connection.

The second part contains a summary of observations on the influence of the various ecological factors. These include the usual factors classified as climatic, physical and chemical, and biotic.

The means of dispersal, the geographic distribution of the various families of algae, the algal populations of various formations, and the periodicity of the algal flora form the topics of the last division of the memoir. The discussion of periodicity is largely drawn from COMERE's previous paper on this subject. The division of the algal flora into vernal, estival, autumnal, and hyemal groups, it should be noted, is really a characterization of the seasons by means of algal reproduction, rather than a classification of algae on the basis of their seasonal phenomena. With regard to the concentration of natural waters, the usual assumption is made that there exists an inverse relation between the height of the water level and the concentration. This leaves out of account the removal of solutes by the adsorption and subsequent settling of the solid particles in these waters, which it seems is much more important in determining concentration than changes in volume. But these points to which exception may be taken are few compared with the great number of topics discussed. —E. N. TRANSEAU.

British North Borneo.—Miss GIBBS[7] has published a notable contribution dealing with the flora of North Borneo. The first part deals with the ecological features of a most interesting region. The general character of the country is discussed, as to its orography and meteorology, and also the general plant-formations under the titles "secondary formations" and "primary forest." A very full itinerary makes the aspects of the flora vivid; and there is a special description of the plant formations on Mt. Kinabalu, the highest mountain of the Malay Archipelago, which was first ascended in 1851 by a botanist, Sir HUGH LOW, then colonial secretary of Labuan.

In the systematic account (184 pp.) of the remarkably large collection of plants made in January to March 1910, Miss GIBBS has had the assistance of several specialists. The collections include plants of all groups from algae to seed plants. Descriptions of about 85 new species, well distributed throughout the families of seed plants, are published, including the following new genera: *Phyllocrater* and *Cowiea* (Rubiaceae), *Sigmatochilus* (Orchidaceae), and *Lophoschoenus* (Cyperaceae). As might be expected, Orchidaceae secure the largest representation of new species, 21 in number. *Elatostema* illustrates how a

[7] GIBBS, LILIAN S., A contribution to the flora and plant formations of Mount Kinabalu and the Highlands of British North Borneo. Jour. Linn. Soc. Bot. **42**: 1–240. *figs. 8. pls. 1–8.* 1914.

genus now and then becomes enriched suddenly in a new region, 7 new species being added to its list. Among the new species is a *Dacrydium*, which means more than a new angiospermous species. The ratio of increase in the number of species as the flora of the tropics becomes known is so great that a new census of the plant kingdom is called for, as the old enumerations, so often quoted in textbooks, are wide of the mark.—J. M. C.

Syncotyly and schizocotyly.—COMPTON[8] has made a somewhat extensive investigation of dicotyledonous seedlings with a single cotyledon, and also of those with more than two cotyledons. The terminology of the title indicates his belief that the single cotyledon of a dicotyledonous seedling is the equivalent of two fused cotyledons; and that extra cotyledons represent a splitting of cotyledons.

The conclusions in reference to syncotyly are in substance as follows: syncotyly occurs in a great number of species, normally or "teratologically"; in species with albuminous seeds syncotyly usually gives rise to a symmetrical cotyledonary tube, the reason probably being "the homogeneity of the surroundings of the embryo before germination"; in species with exalbuminous seeds syncotyly is usually asymmetrical, the cotyledons uniting along one edge only, the suggested reason being "the asymmetry of its [embryo] environment, which produces accumbency and other irregularities."

The study of schizocotyly is made the basis of a discussion as to the primitive condition of cotyledony. Arguments have been advanced for both dicotyledony and polycotyledony as the primitive condition. The author's judgment inclines to dicotyledony as the primitive condition. If this historical question must be settled, it will probably have to await the discovery of the embryos of Cycadofilicales.—J. M. C.

Tyloses.—The extensive collections of the Forest Products Laboratory have enabled Miss GERRY to undertake a survey of the occurrence of tyloses.[9] Of the 45 genera of hardwoods examined, 24 are found to contain tyloses. These proliferous growths into the vessels naturally reach their most marked development in ring-porous woods, such as oak, although in this genus black oaks rarely show tyloses, while white oaks show abundant evidences. Woods in which parenchyma surrounds the vessels show the best development of tyloses, though the proximity of medullary rays to vessels is also a factor. Contrary to previous accounts, Miss GERRY finds tyloses in the sap wood of all species in which they occur in the heart wood, and she produces photographs of hickory which illustrate the point. With respect to soft woods, *Pinus* is the only genus in which true tyloses have been found, and here they are held

[8] COMPTON, R. H., An anatomical study of syncotyly and schizocotyly. Ann. Botany **27**:793–821. *figs. 41.* 1913.

[9] GERRY, E., Tyloses; their occurrence and practical significance in some American woods. Jour. Agric. Research **1**:445–470. *pls. 52–59.* 1914.

to be of normal occurrence (contrary to RAATZ, but agreeing with the reviewer). They are found to be better developed in spring wood than in summer wood, and more numerous in sap wood than in heart wood. The effect of tyloses on penetration of wood by preservatives is also discussed.—M. A. CHRYSLER.

The Congo flora.—WILDEMAN[10] has published a list of the recorded plants from the state of Congo, which adds much to our knowledge of the African flora. In addition to the vascular plants, the list includes the fungi, of which 145 species are enumerated. The new species of fungi number 16, and the following new genera are described: *Volutellopsis* and *Gilletia* (Mucedinaceae). The ferns enumerated are 35, and among them is a new species of *Dryopteris*. About 130 monocotyledons are enumerated, and 63 of these are grasses. The dicotyledons, of course, are far the most numerous, about 700 species being listed. Among them 25 new species are described, but 15 of these belong to the leguminous genus *Geissaspis*, an addition that doubles the number of its species. A student in the north temperate regions expects the Compositae to be the dominant dicotyledonous family; but in the Congo region the Leguminosae are dominant, being represented in this list by 176 species, while the Compositae reach only 62 species.—J. M. C.

Embryogeny of Ranunculaceae and Cruciferae.—In continuing his studies of the embryo of Ranunculaceae, SOUÈGES[11] has attacked the genus *Ranunculus*, recording every stage in the embryogeny with great detail and excellent illustrations. The same investigator[12] has also made a preliminary announcement of additional details observed in the embryogeny of crucifers.—J. M. C.

South African mosses.—South Africa is beginning to yield its quota of new mosses, as is evidenced by a publication from WAGER[13] of the Transvaal University College, Pretoria. Ten new species are described, representing ten genera. The author promises an early publication of a list of all the mosses recorded from South Africa.—J. M. C.

New orchids of the oriental tropics.—As the vegetation of the tropics is investigated more intensively, the number of new species discovered is always surprising. In a recent contribution, SMITH[14] has described 26 new species of orchids from the Malay Archipelago, and 40 new species from Papua.—J. M. C.

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[10] WILDEMAN, E. DE, Aaditions á la flore du Congo. Bull. Jard. Bot. Bruxelles **4**:1–241. 1914.

[11] SOUÈGES, R., Recherches sur l'embryogénie des Renonculacées. Bull. Soc. Bot. France **60**:506–514, 542–549. *figs. 354–427*. 1913.

[12] ———, Nouvelles observations sur l'embryogénie des Crucifères. Compt. Rend. **158**:1356. 1914.

[13] WAGER, HORACE A., Some new South African mosses. Trans. Roy. Soc. South Africa **4**:1–6. *pls. 1, 2*. 1914.

[14] SMITH, J. J., Bull. Jard. Bot. Buitenzorg. II. no. 13. pp. 77. 1914.